SECR2033
Computer Organization and Architecture

Lecture slides prepared by “Computer Organization and Architecture”, 9/e, by William Stallings, 2013.

Module 1
Introduction

Objectives:

- To study of computers with a brief history that serves the purpose of providing an overview of computer structure and functions.
- To differentiate between computer architecture and computer organization.
- To understand what makes a computer system tick before attempt to optimize the programs that it runs.

Module 1

Introduction

Module 1
Introduction

1.1 An Overview

1.2 Components of Computer

1.3 Computer Structure and Functions

1.4 Computer Evolution

1.5 Computer Level Hierarchy

1.6 An Example System

1.7 Summary

- The Computer Family
- Computer Types

1.1 An Overview

- This subject is about the structure and function of computers in order to differentiate the nature and characteristics of modern-day computers clearly.

- This task is challenging because:

1) Variety of computer products from a single-chip microcomputers to supercomputers.
   - Variety not only in cost, but also in size, performance, and application.
2) Rapid changes in all aspect that characterized computer technology continuously.

William Stallings (2013). *Computer Organization and Architecture: Designing for Performance* (9th Edition). United States: Pearson Education Limited, p.29.

- In describing computers, a distinction is often made between computer architecture and computer organization.

Computer architecture	Computer organization
Refer to those attributes of a system: • that visible to a programmer • Have a direct impact on the logical execution of a program.	Refer to the operational units and their interconnections that realize the architectural specification.

How do I design a computer?

How does a computer work?

William Stallings (2013). *Computer Organization and Architecture: Designing for Performance* (9th Edition). United States: Pearson Education Limited, p.29.
Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.2.

- Computer architecture and organization include many elements to be addressed:

Computer architecture	Computer organization
• *Instruction sets & formats.*	• *Control signal*
• *Operation codes.*	• *Signaling method*
• *Data types*	• *Memory types.*
• *Number & types of registers*	
• *Addressing modes.*	
• *Memory access methods.*	
• *I/O mechanisms.*	

The Computer Family

- Many computer manufacturers offer a family of computer models, all with the same architecture but with differences in organization.
- All Intel x86 family share the same basic architecture.
- The IBM System/370 architecture first introduced in 1970 included a number of models that share the same basic architecture and has survived to this day as the architecture of IBM's mainframe product line.
- The newer models retained the same architecture so that the customer's software investment was protected (code compatibility).

1933 vs. 1948 Chevrolet

From whittling a 2x4 to a smooth clay styling model

1948 vs. 1963 Ford

From fat fendered to smooth, integrated design

1963 vs. 1978 Volkswagen

From 1930s Hitler to 1970s sharp-edged Giugiaro

1978 vs. 1993 Lincoln

From brick to jelly bean

1993 vs. 2008 Toyota

Miniscule style evolution

www.joesherlock.com

Same architecture BUT different in organization !

One advantage having the SAME architecture is that the same software can be used in the newer computer models with DIFFERENT computer organization.

Why study computer architecture and computer organization?

- To design better programs, including system software such as compilers, operating systems, and device drivers.
- To optimize program behavior.
- To evaluate (benchmark) computer system performance.
- To understand time, space, and price tradeoffs.
  - *e.g.* Solving calculation in less time but more memory.

Computer Types

- Computers can be generally classified by size and power as follows, though there is considerable overlap:

- **Personal Computer (PC)**:
  A small, single-user computer based on a microprocessor.

- **Workstation:** A powerful, single-user computer. A workstation is like a PC, but it has a more powerful microprocessor and, in general, a higher-quality monitor.

https://www.syniaditsolutions.co.uk/wp-content/uploads/2017/12/computer-HAM.jpg | https://www.dpreview.com/files/p/articles/4907218890/HPZ8.jpeg

- **Minicomputer**: A multi-user computer capable of supporting up to hundreds of users simultaneously.

- **Mainframe**: A <u>powerful multi-user computer</u> capable of supporting many hundreds or thousands of users simultaneously.

http://3.bp.blogspot.com/-9L_4vswIwVM/Tc5XGFZ23rI/AAAAAAAADJI/4n9pU3lxF64/s1600/ibm+as+400.jpg
https://images.idgesg.net/images/article/2017/07/ibm_z_1-100729283-large.jpg

- **Supercomputer**: An extremely fast computer that can perform hundreds of millions of instructions per second.

THE WORLD'S FASTEST SUPERCOMPUTER IS BACK IN AMERICA

Meet Summit

By Micah Singleton | @MicahSingleton | Jun 12, 2018, 4:35pm EDT

- **Mobile Devices :**

  A computing device that small enough to hold and operate in the hand (like smartphones, PDAs etc).

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http://www.northstarbusinessessentials.com/wp-content/uploads/2015/10/Mobile-devices.jpg

Module 1
Introduction

1.2 Components of Computer

■ Computers : Definition

- An electronic device for storing and processing data, typically in binary form, according to instructions given to it in a variable program.

- An electronic device designed to accept data, perform prescribed mathematical and logical operations at high speed, and display the results of these operations.

Keywords: *store*, *process*, *input/output (I/O)*

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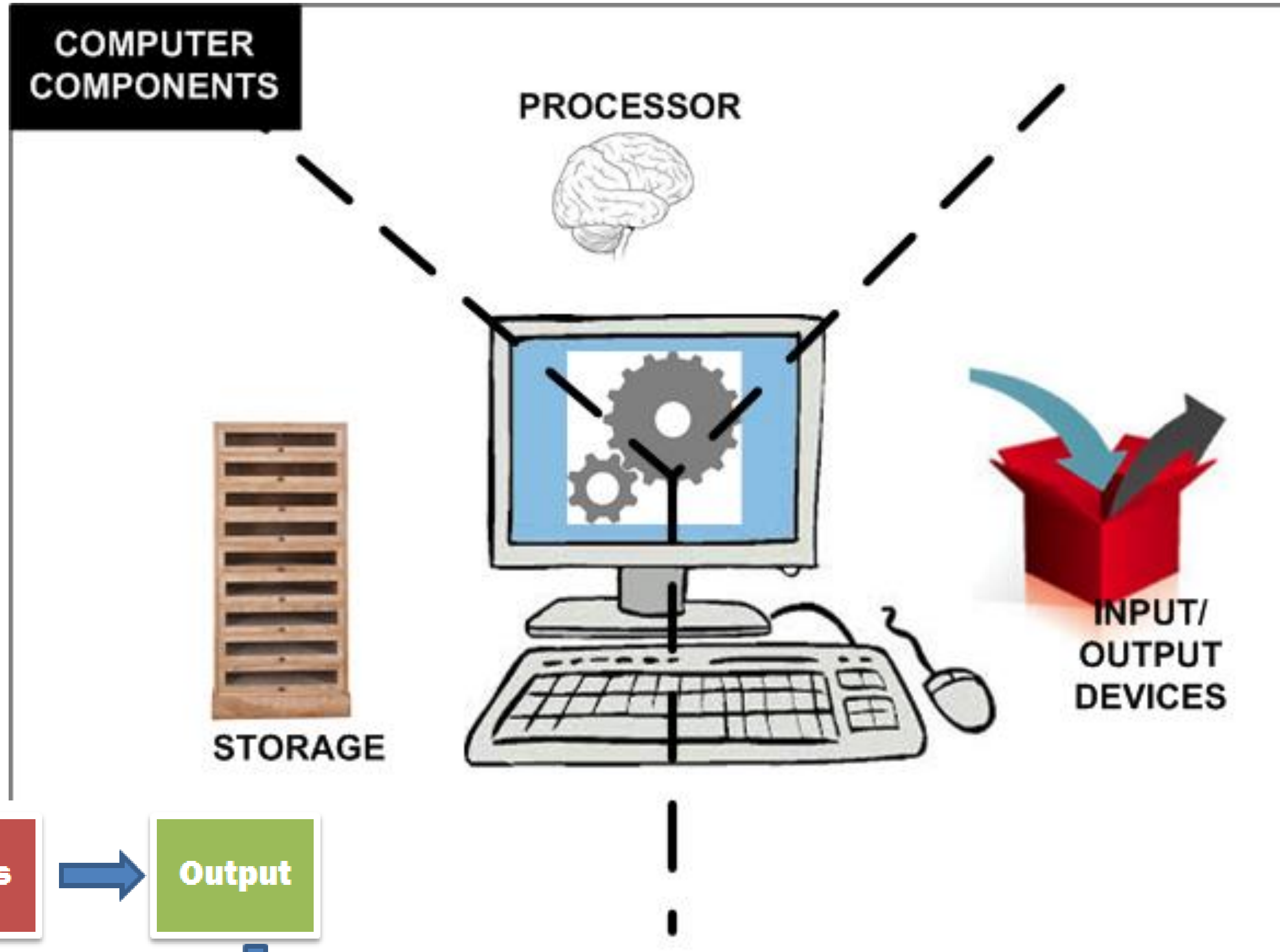
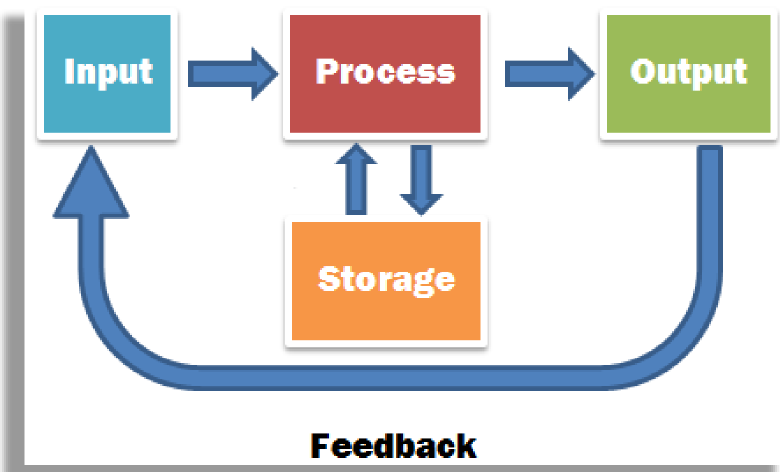




http://4.bp.blogspot.com/-stkMd3hICVM/UGMr-gn0ceI/AAAAAAAAABE/UfswB30BZE8/s1600/Input-Process-Output.png

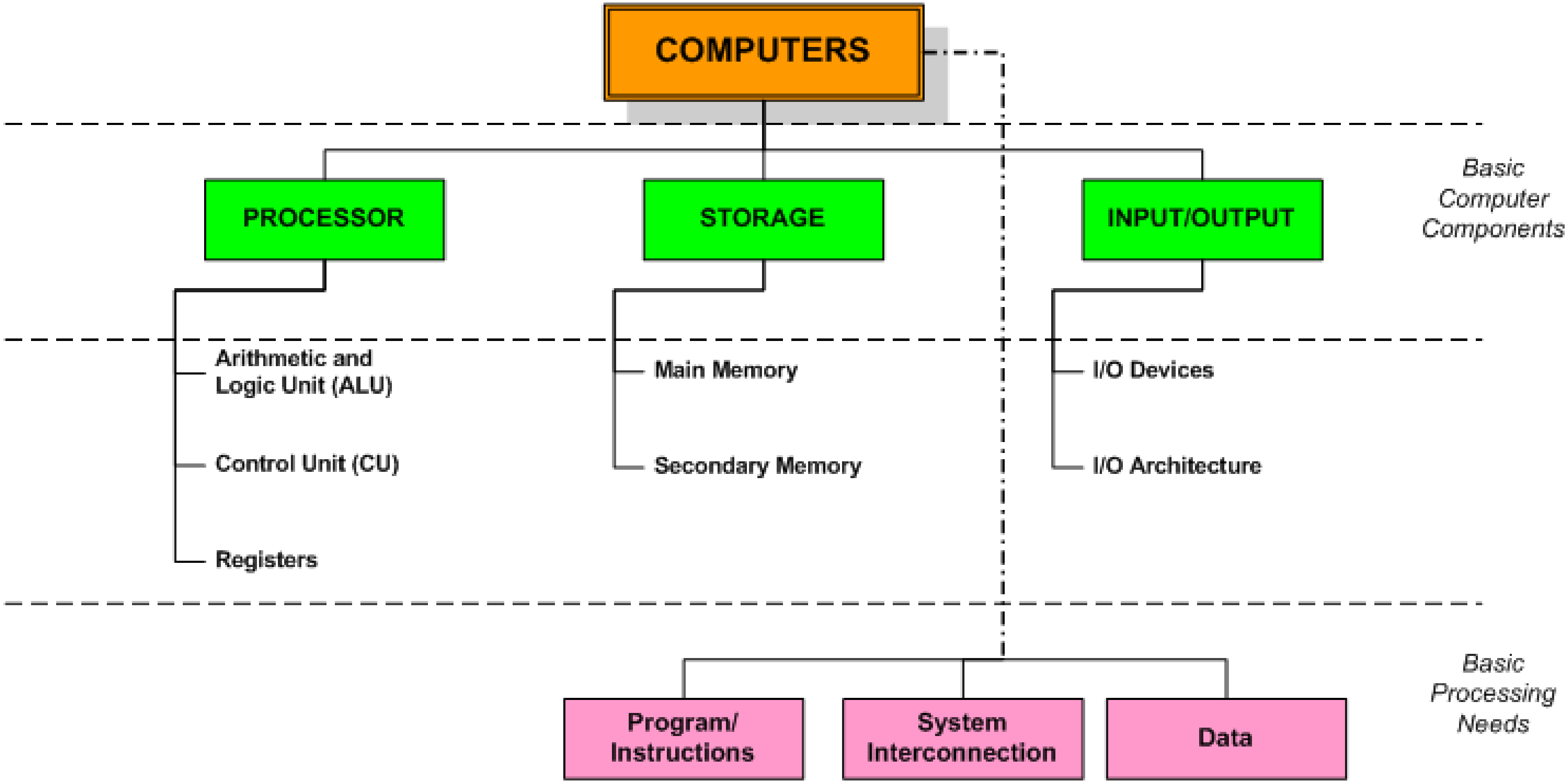


Figure: Computer components in detail

Module 1

Introduction

- Overview
- Structure
- Functions
- Program

1.3 Computer Structure & Functions

- A computer is a complex system with a hierarchical system of interrelated subsystems with different levels.
- At each level, the designer is concerned with structure and function:

Structure	Functions
The way in which the components are interrelated.	The operation of each individual component as part of the structure.

William Stallings (2013). *Computer Organization and Architecture: Designing for Performance* (9th Edition). United States: Pearson Education Limited, p.30.

CPU (Control Processing Unit)
I/O (Input/Output)
ALU (Arithmetic Logic Unit)

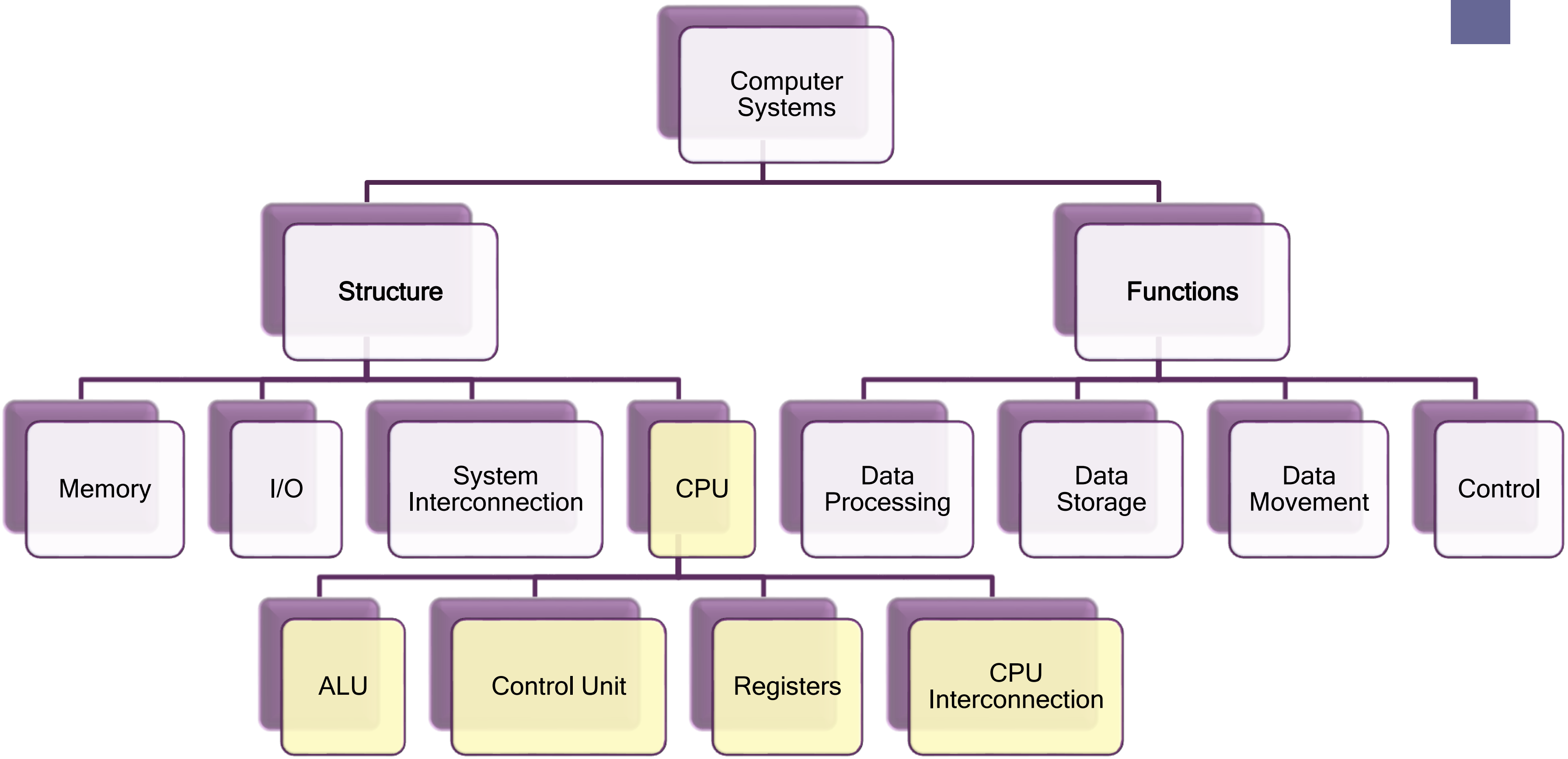
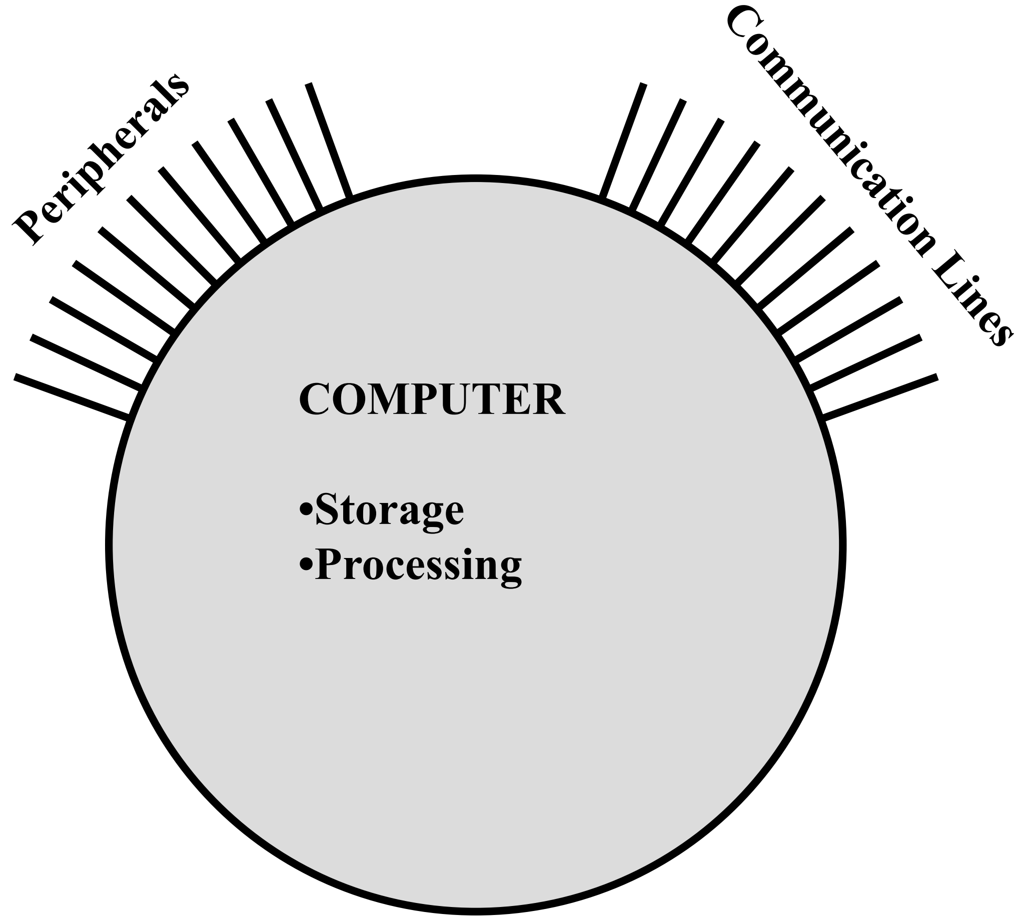


Figure: Computer components in each level

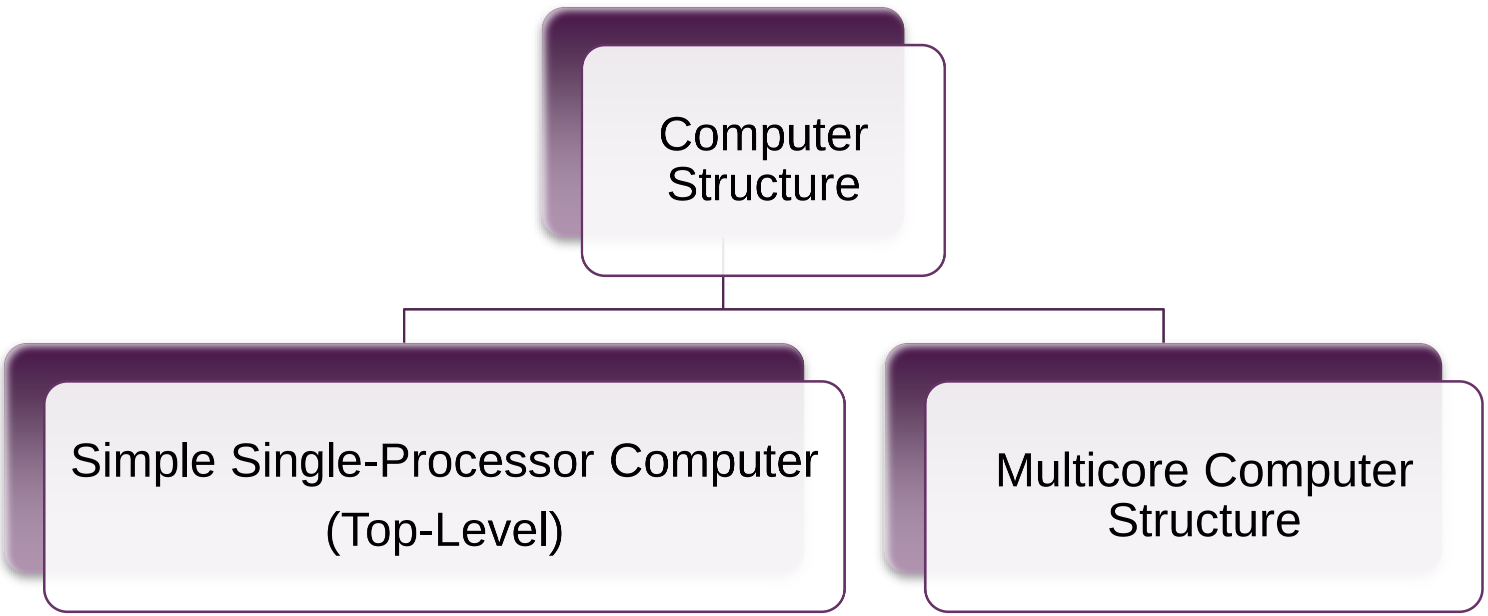
Structure

- The simplest possible depiction of a computer:



Structure

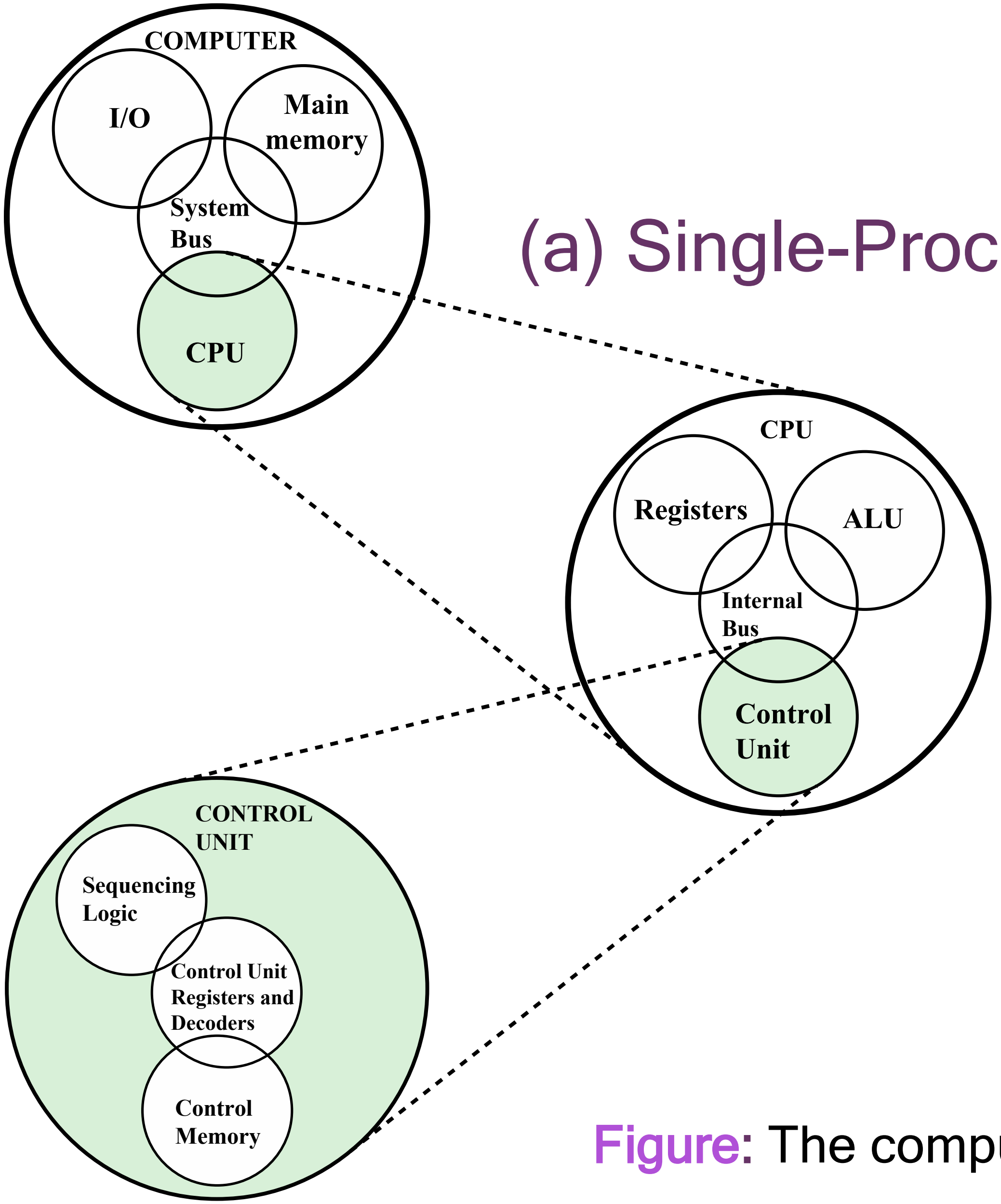
- General way of the internal structure of a computer:



(Traditional Computer)

Structure

(a) Single-Processor Computer



- The greater concern is the internal structure of the computer itself :

Figure: The computer: Top-Level structure

William Stallings (2013). *Computer Organization and Architecture: Designing for Performance* (9th Edition). United States: Pearson Education Limited, p.35.

Table: The task for each structural component.

Components	Task
CPU *(Processor)*	Controls the operation of the computer and performs its data processing functions.
Memory	Stores data.
I/O	Moves data between the computer and its external environment.
System Interconnection *(System bus)*	Mechanism for communication among CPU, main memory, and I/O.

Table: The major structural components of CPU.

Components	Task
ALU	Performs the computer's data processing functions.
Control Unit (CU)	Controls CPU operations.
Registers	Provides internal storage to the CPU.
CPU Interconnection	Mechanism for communication among the ALU, Control Unit, and Registers.

William Stallings (2013). *Computer Organization and Architecture: Designing for Performance* (9th Edition). United States: Pearson Education Limited, p.34.

(b) Multicore Computer Structure

- Generally, the contemporary computers have multiple processors.
- All processors reside on a single chip.
- Each processing units (CU, ALU, registers) is called a core.
- The use of multiple layers of memory is called cache memory.

CPU (Control Processing Unit)
I/O (Input/Output)

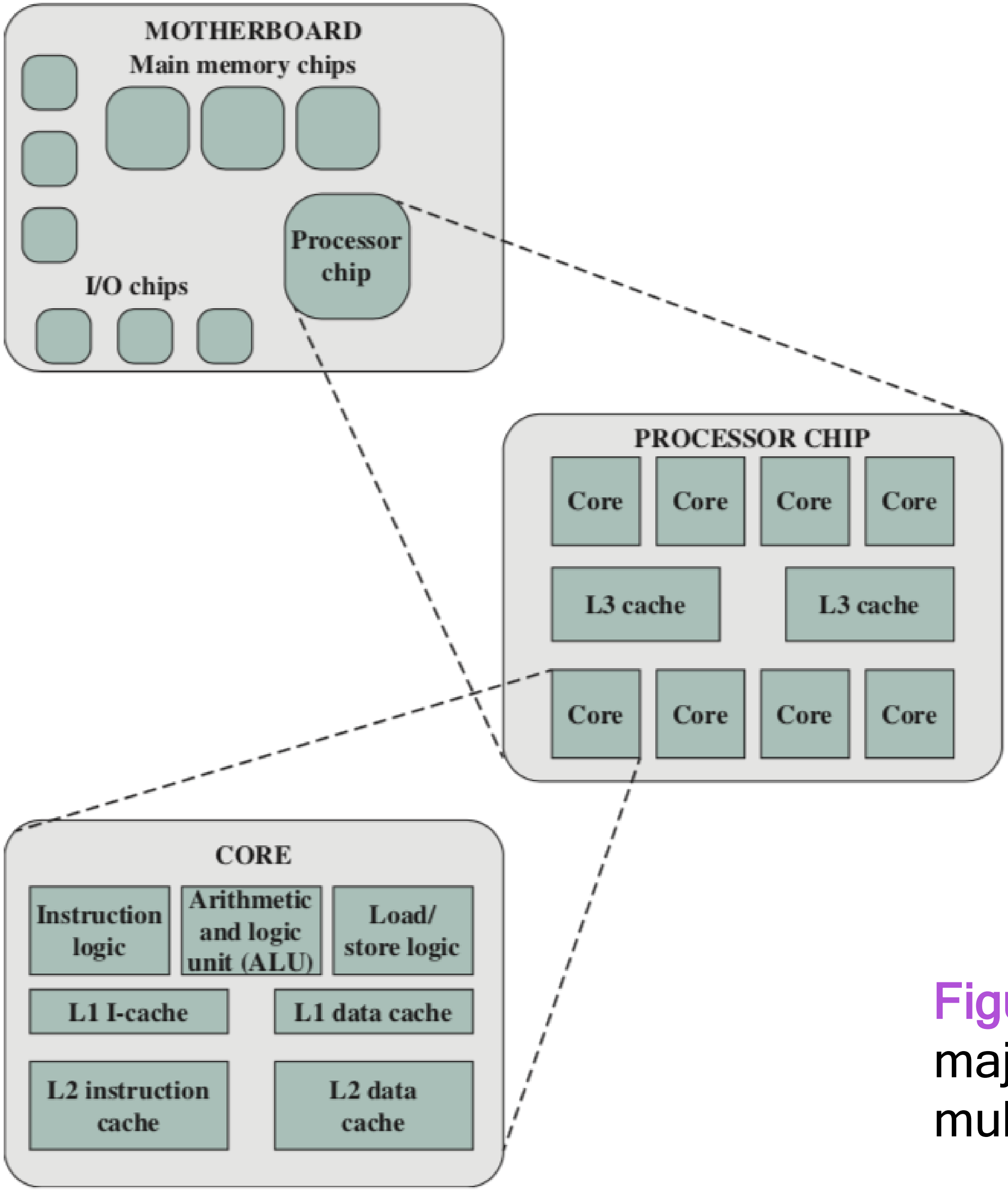
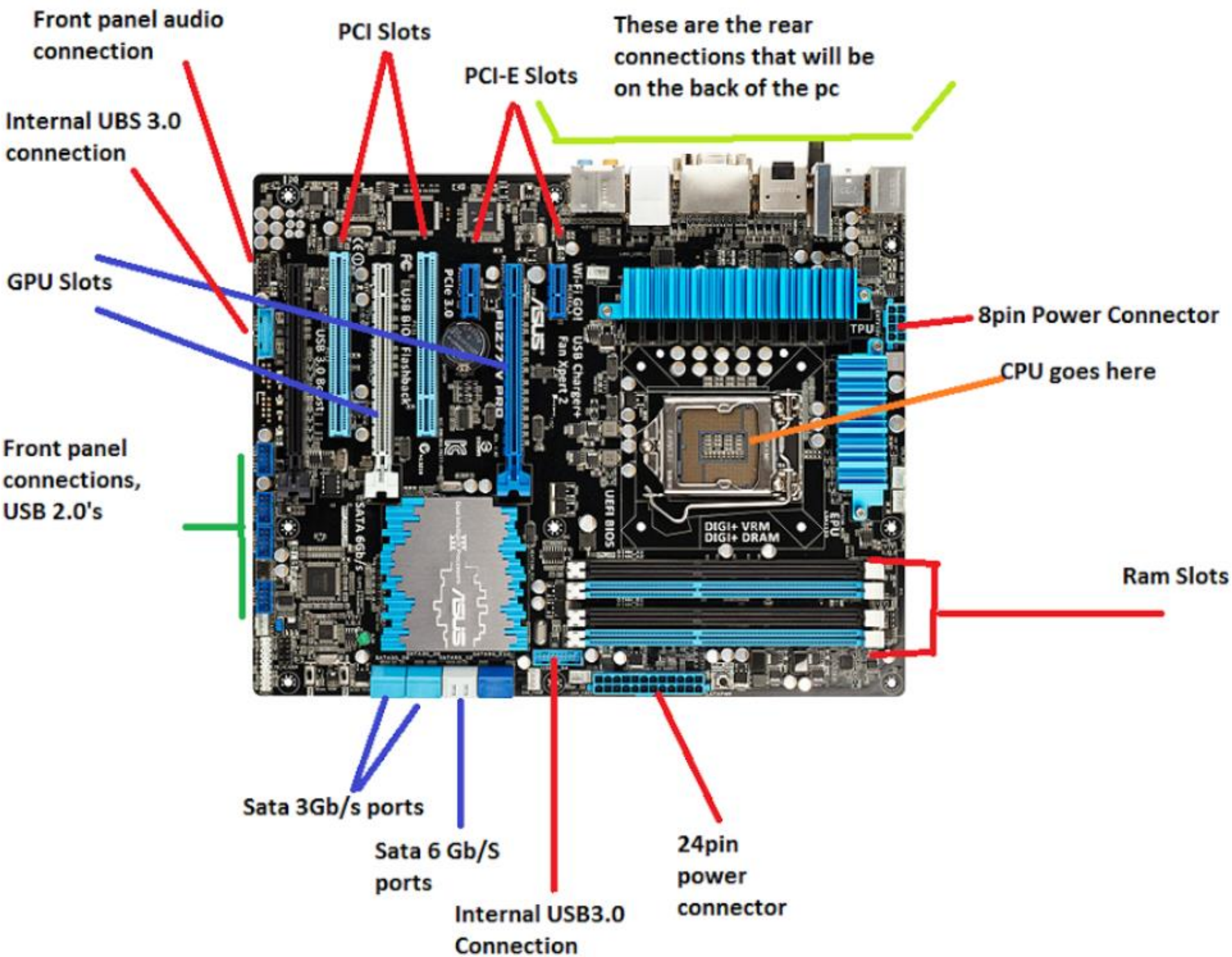
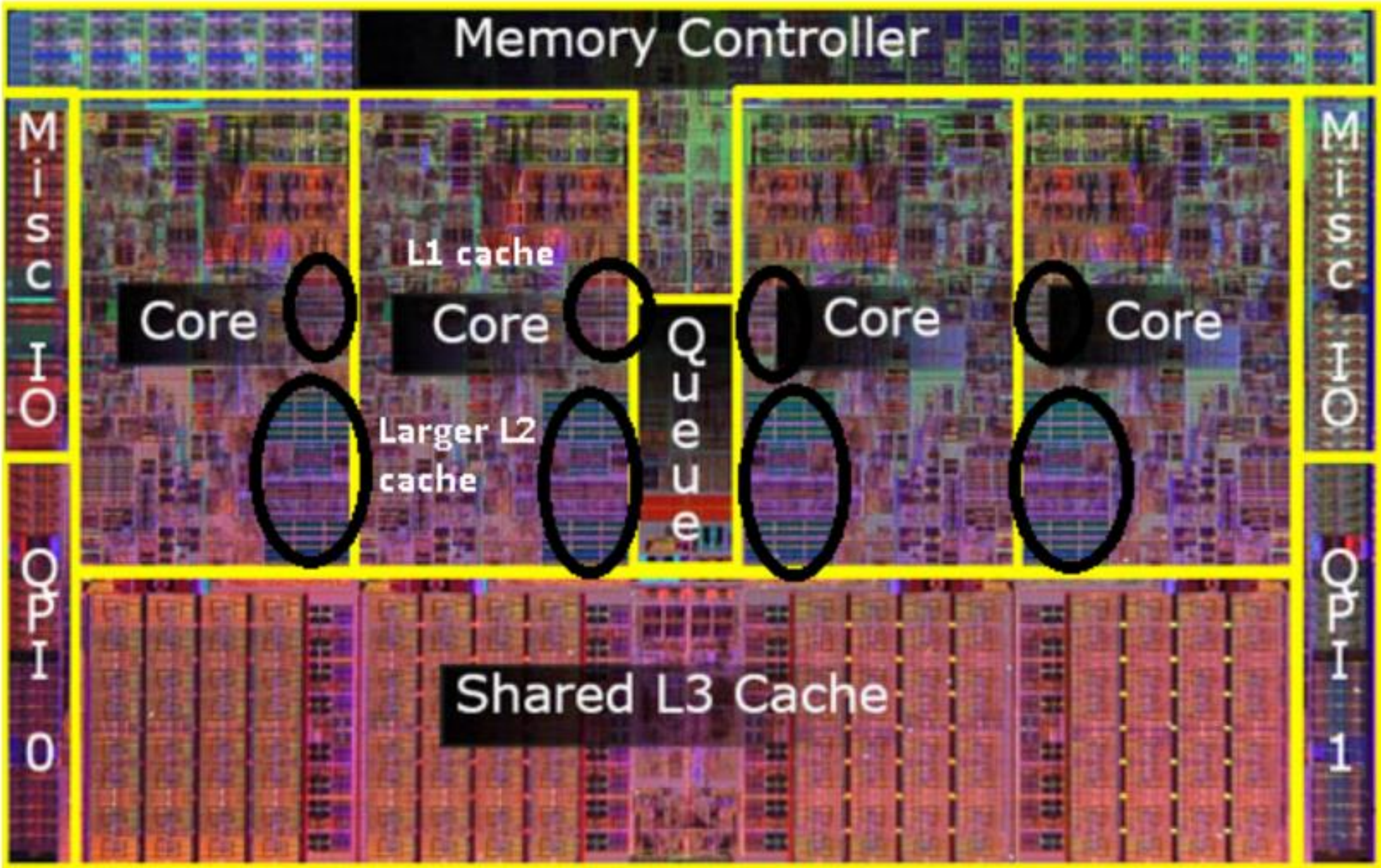


Figure: Simplified view of major elements of a multicore computer


Front panel audio connection
PCI Slots
PCI-E Slots
These are the rear connections that will be on the back of the pc
Internal UBS 3.0 connection
GPU Slots
8pin Power Connector
CPU goes here
Front panel connections, USB 2.0's
Ram Slots
Sata 3Gb/s ports
Sata 6 Gb/S ports
Internal USB3.0 Connection
24pin power connector



L1, L2 and L3 cache in a four core processor (credit)

Figure: A typical computer advertisement.

Video 1 – Cache memory

- What is cache memory? L1, L2 and L3? Please watch the YouTube video
- https://www.youtube.com/watch?v=IA8au8Qr3lo

Functions

- Both the structure and functioning of a computer are simple.
- Figure depicts the basic functions that a computer can perform.
- In general terms, there are only four:
  - Data processing
  - Data storage
  - Data movement
  - Control

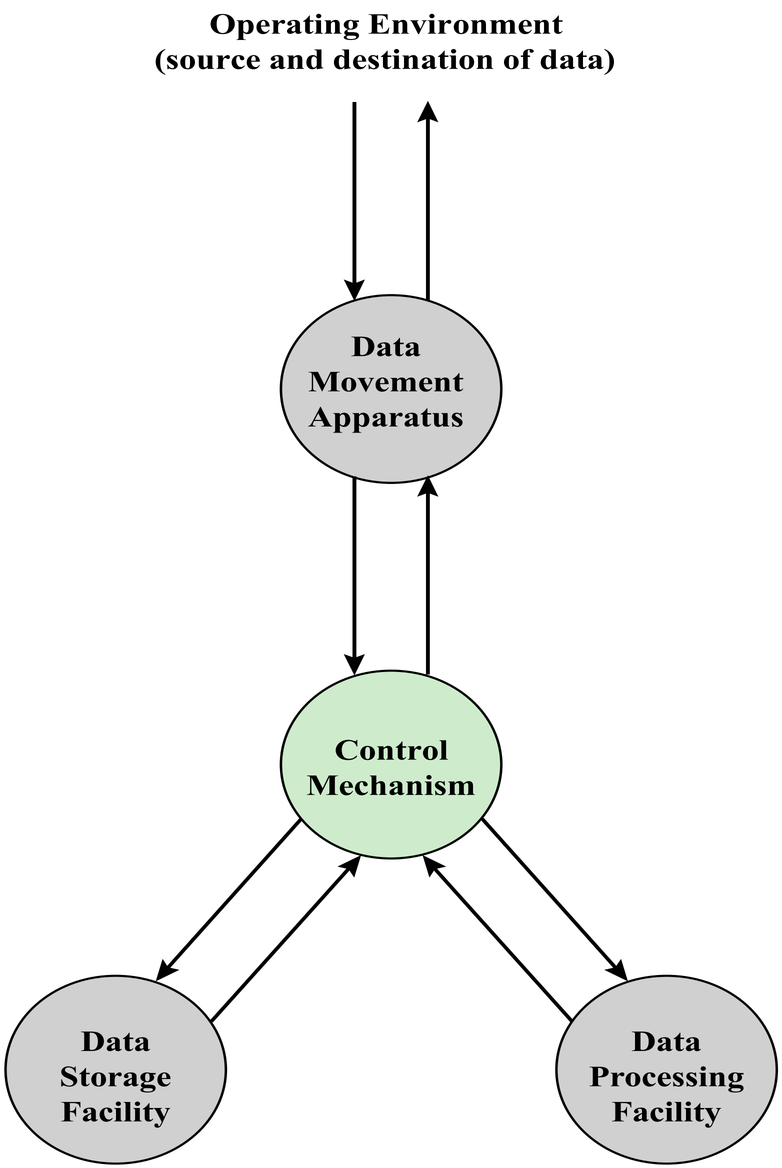


Figure: A functional view of the computer.

Table: The task for each function component.

Functions	Task
Data Processing	Process data in variety of forms and requirements.
Data Storage	Short and long term data storage for retrieval and update.
Data Movement	Moves data between the computer and outside world.
Control	Control of process, move and store data using instruction.

Functions are performed through ***programs***

Program

- A sequence of steps.
- For each step, a computer function is executed.
- For each operation:
  - a different/new set of control signals is needed.
  - a unique code (instruction) is provided. *e.g.* `ADD`, `MOVE`
- A hardware segment accepts the code and issues the control signals.

Program: Execution

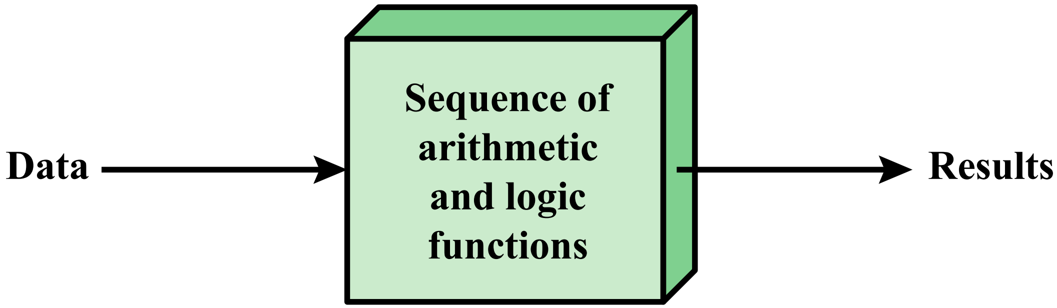
- Two approaches:

Approach 1: Hardwired

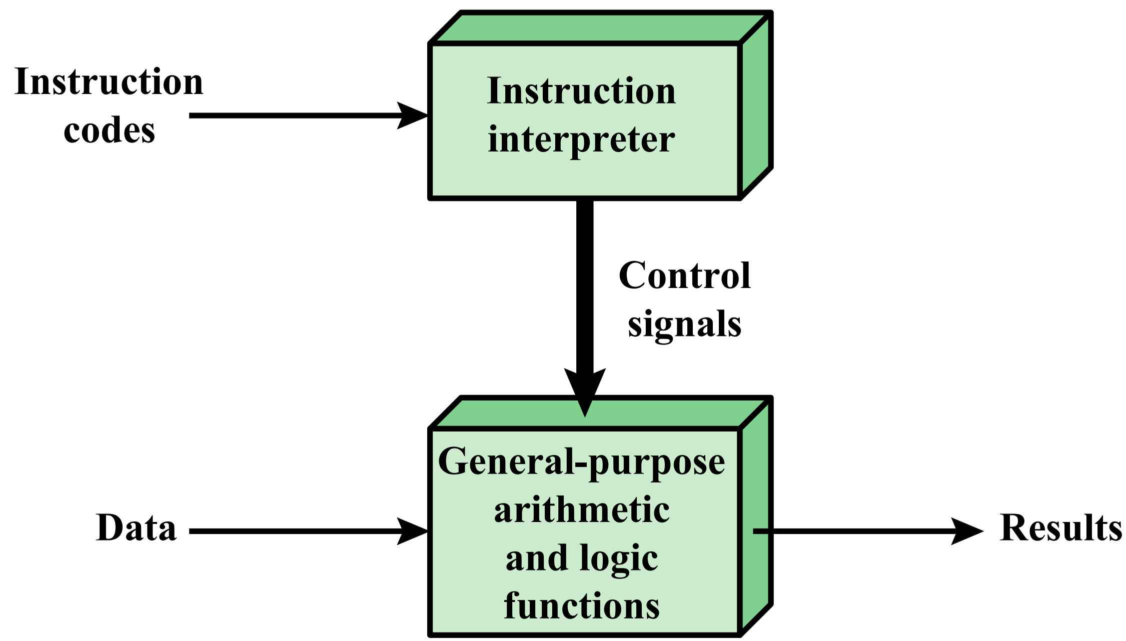
- Built into (wired into) computers hardware.
- Uses a sequence of arithmetic and logic functions
- Provides high speed but inflexible to change.

Approach 2: Software

- Control signals through instruction codes.
- Needs an interpreter to “speak machine”.
- While less speed, it is easily reprogrammable.



(a) Programming in hardware



(b) Programming in software

Figure: Hardware and software approaches.

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1.6 An Example System

1.7 Summary

- Historical Development

1.4 Computer Evolution

1

Historical Development

- The evolution of computers can be divided into generations.
- Each generation being defined by the technology used to build the machine.

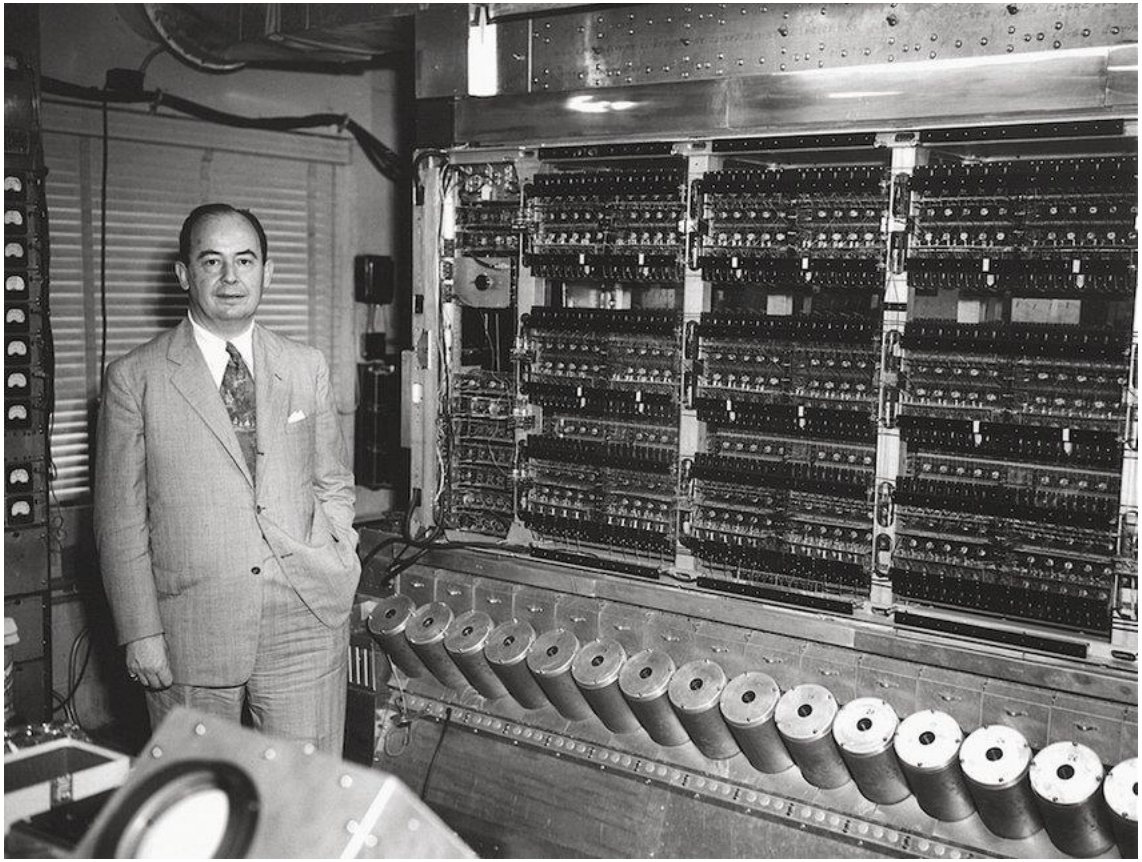
Gen.	Years	Technology	Typical Speed (Operation / sec)
0	1642 – 1946	Mechanical Calculating Machines	< 40,000
1st	1946 – 1957	Vacuum Tube Computers	40,000
2nd	1957 – 1964	Transistorized Computers	200,000
3rd 4th	1965 – 1978	Integrated Circuit Computers	1,000,000
5th	1978 – 1991	Very large scale integration (VLSI)	100,000,000
6th	1991 – ????	Ultra large scale integration (ULSI)	> 1,000,000,000

Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.12.
William Stallings (2016). *Computer Organization and Architecture: Designing for Performance* (10th Edition). United States: Pearson Education Limited, p.17.

1st Generation: The von Neumann Model

(pronounced *von noy-man*)

- In the earliest electronic computing machines, programming was synonymous with connecting wires to plugs.



William Stallings (2013). *Computer Organization and Architecture: Designing for Performance* (9th Edition). United States: Pearson Education Limited, p.39.
Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.27-30.
https://pbs.twimg.com/media/DcHPdYZV4AAPZb3.jpg

- No layered architecture existed, so programming a computer was as much of a feat of electrical engineering as it was an exercise in algorithm design.
- All stored-program computers have come to be known as *von Neumann systems* using the *von Neumann architecture* (model).

William Stallings (2013). *Computer Organization and Architecture: Designing for Performance* (9th Edition). United States: Pearson Education Limited, p.39.
Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.27-30.

- This von Neumann model used for designing and building the first generation (Vacuum Tubes Computer).

- The model based on the following three characteristics :

1. The computer consists of four main sub-systems: *(Memory, ALU, Control Unit, I/O)*
2. Program is stored in memory during execution.
3. Program instructions are executed sequentially.

Single path is often referred to as the:

von Neumann bottleneck [2]

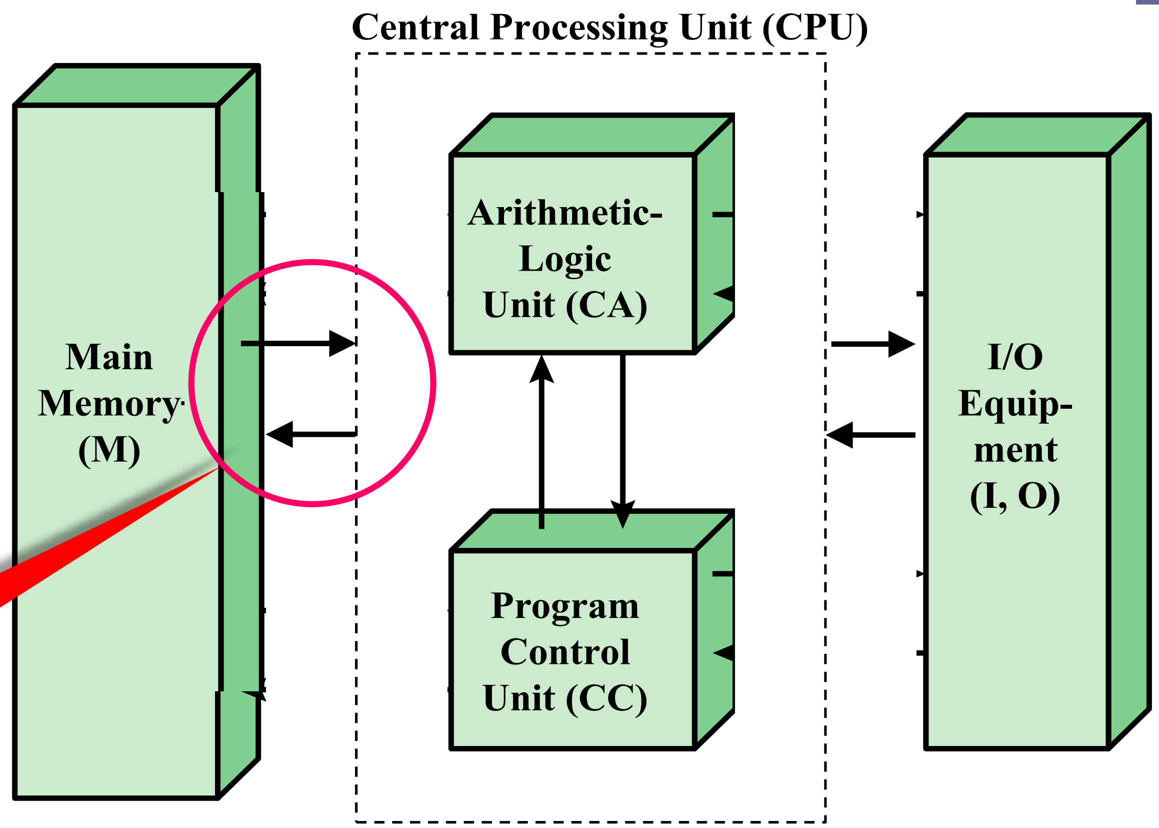


Figure: Structure of von Neumann machine.

1 William Stallings (2013). *Computer Organization and Architecture: Designing for Performance* (9th Edition). United States: Pearson Education Limited, p.40.
2 Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.28.

- Conventional stored-program computers have undergone many incremental improvements over the years.

- These improvements include adding specialized buses, floating-point units, and cache memories, to name only a few.

- Departure from the classic von Neumann architecture → hence the non von Neumann model.

1st Generation: The Non von Neumann Model

- Adding processors and parallel processing are examples of approaches in a *non* von Neumann model.
  - Adding processors can increase computational throughput.
  - Parallel computers improve speed by doing multiple tasks at one time.

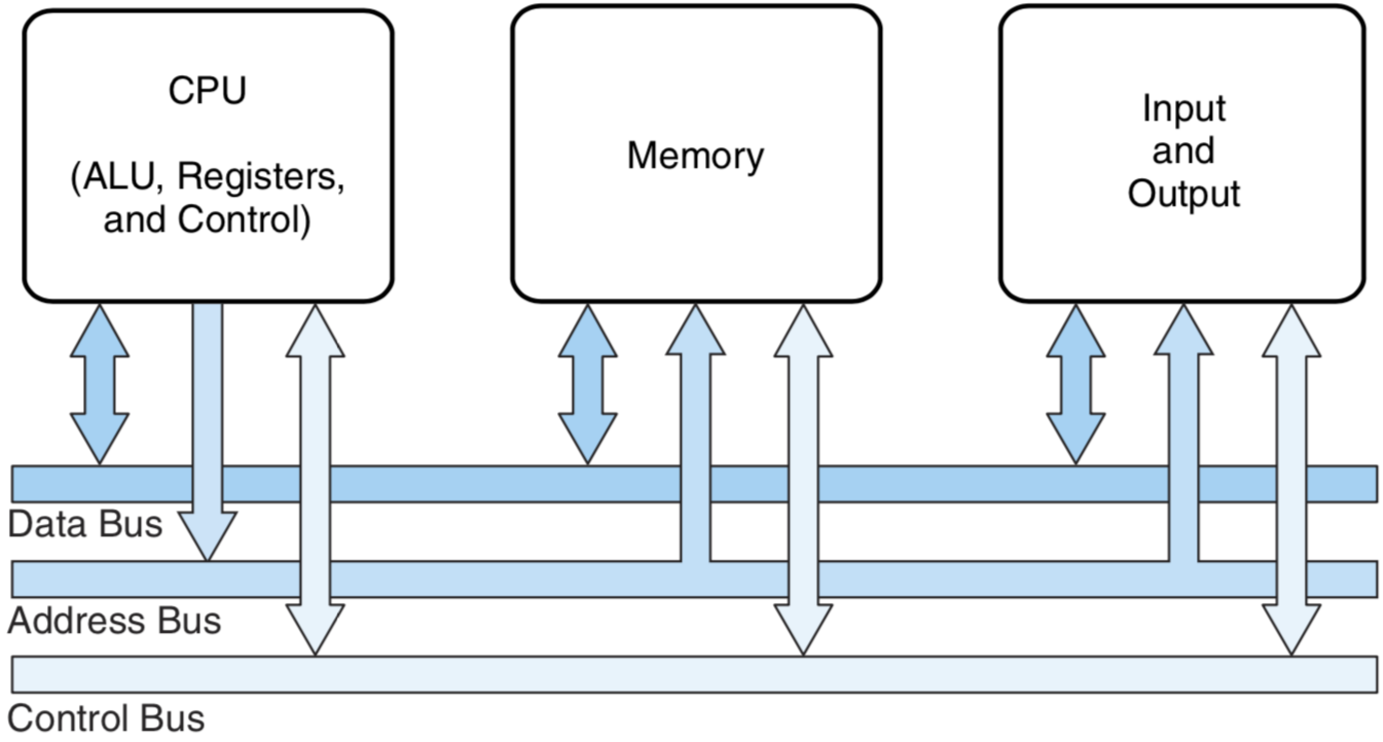


Figure: The modified von Neumann architecture, adding a system bus.

Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.30.

Processors:

- In the late 1960s, high-performance computer systems were equipped with dual processors to increase computational throughput.
- In the 1970s supercomputer systems were introduced with 32 processors.
- Supercomputers with 1,000 processors were built in the 1980s.
- In 1999, IBM announced its *Blue Gene* system containing over 1 million processors.

https://upload.wikimedia.org/wikipedia/commons/d/d3/IBM_Blue_Gene_P_supercomputer.jpg

Parallel Processing:

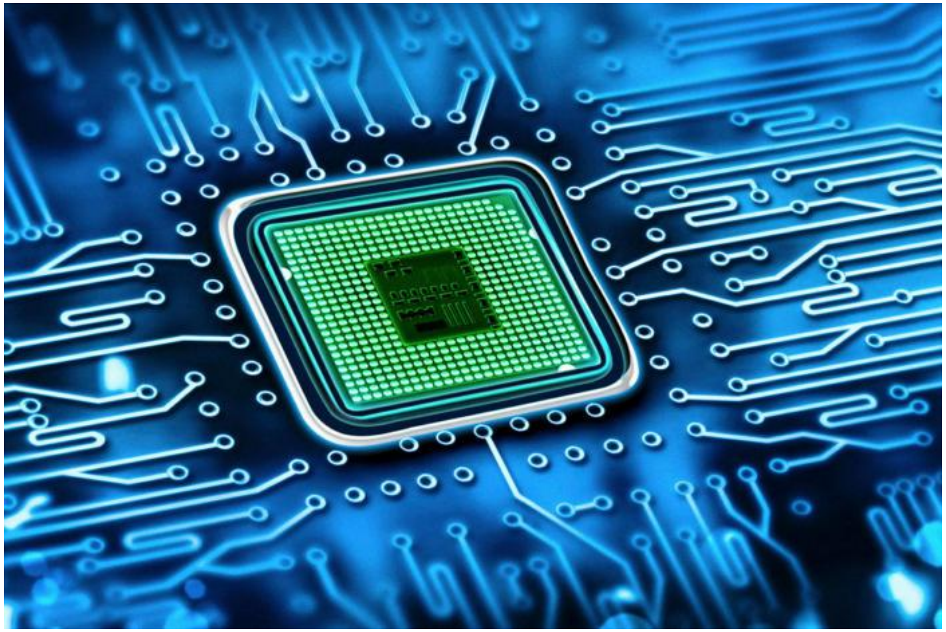
- Parallel processing is currently the most popular and the only one method of providing increased computational power.
- More radical systems have reinvented the fundamental concepts of computation.
- These advanced systems include genetic computers, quantum computers, and dataflow systems.

- At this point, it is unclear whether any of these systems will provide the basis for the next generation of computers.

Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.30.

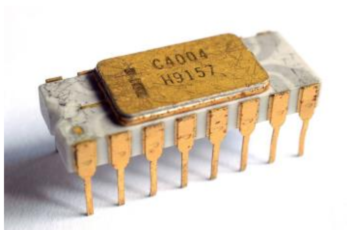
4th Generation: Microprocessors

- Microprocessor : all CPU components on a single chip.

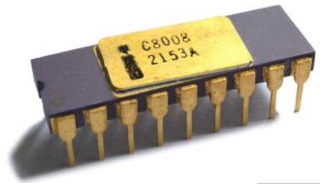


- The more elements were placed on each chip, so that fewer chips were needed to construct a single computer processor.

William Stallings (2013). *Computer Organization and Architecture: Designing for Performance* (9th Edition). United States: Pearson Education Limited, p.57.



Intel 4004



Intel 8008

Intel 8080

1971

- First microprocessor
- 4 bits

1972

- 8 bits
- Both designed for specific applications.

1974

- Intel's first general purpose microprocessor
- Designed to be the CPU of a general purpose microcomputer.

Used in first personal computer – Altair

Figure: Early Evolution of Intel Processors

The Evolution of the Intel x86 Architecture

- Intel has ranked as the number 1 maker of microprocessors for non-embedded systems for decades.

- 8086
  - much more powerful.
  - 16 bits
  - instruction cache, pre-fetch few instructions.
  - 8088 (8 bit external bus) used in first IBM PC.

- 80286
  - 16 MB memory addressable.

- 80386
  - First 32 bit design.
  - Support for multitasking that run multiple programs at the same time.

- 80486
  - sophisticated powerful cache and instruction pipelining.
  - built in maths co-processor.
- Pentium
  - Superscalar technique - multiple instructions executed in parallel.

- Pentium Pro
  - Increased superscalar organization.
  - Aggressive register renaming.
  - branch prediction.
  - data flow analysis.
  - speculative execution.

- Pentium II
  - MMX technology
  - graphics, video and audio processing.
- Pentium III
  - Additional floating point instructions for 3D graphics.
- Pentium 4
  - Further floating point and multimedia enhancements.
- Itanium
  - 64 bit.
- Core Duo
  - starts of a multicore processor.
- Quad Core

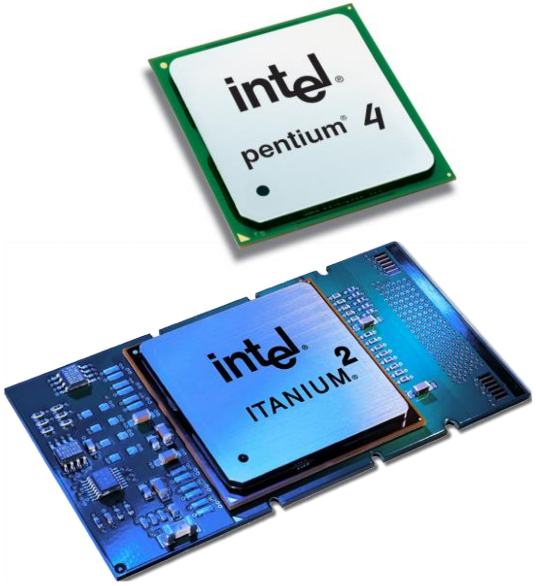


Table: (a) 1990s processors (b) Recent processors.

(a)

	486TM SX	Pentium	Pentium Pro	Pentium II
Introduced	1991	1993	1995	1997
Clock speeds	16–33 MHz	60–166 MHz,	150–200 MHz	200–300 MHz
Bus width	32 bits	32 bits	64 bits	64 bits
Number of transistors	1.185 million	3.1 million	5.5 million	7.5 million
Feature size (μm)	1	0.8	0.6	0.35
Addressable memory	4 GB	4 GB	64 GB	64 GB
Virtual memory	64 TB	64 TB	64 TB	64 TB
Cache	8 kB	8 kB	512 kB L1 and 1 MB L2	512 kB L2

(b)

	Pentium III	Pentium 4	Core 2 Duo	Core i7 EE 4960X
Introduced	1999	2000	2006	2013
Clock speeds	450–660 MHz	1.3–1.8 GHz	1.06–1.2 GHz	4 GHz
Bus width	64 bits	64 bits	64 bits	64 bits
Number of transistors	9.5 million	42 million	167 million	1.86 billion
Feature size (nm)	250	180	65	22
Addressable memory	64 GB	64 GB	64 GB	64 GB
Virtual memory	64 TB	64 TB	64 TB	64 TB
Cache	512 kB L2	256 kB L2	2 MB L2	1.5 MB L2/15 MB L3
Number of cores	1	1	2	6

L1 (Level 1 – closest to the core)

William Stallings (2016). *Computer Organization and Architecture: Designing for Performance* (10th Edition). United States: Pearson Education Limited, p.26-27.

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1.5 Computer Level Hierarchy

1.6 An Example System

1.7 Summary

- Overview
- Layers in Virtual Machines

1.5 Computer Level Hierarchy

Overview

- Computers consist of many things besides chips.
- Before a computer can do anything worthwhile, it must also use software.
- Writing complex programs requires a "*divide and conquer*" approach, where each program module solves a smaller problem.
- Complex computer systems employ a similar technique through a series of virtual machine layers.

Layers in Virtual Machines

- Each virtual machine layer is an abstraction of the level below it.
- The machines at each level execute their own particular instructions, calling upon machines at lower levels to perform tasks as required.
- Computer circuits ultimately carry out the work.

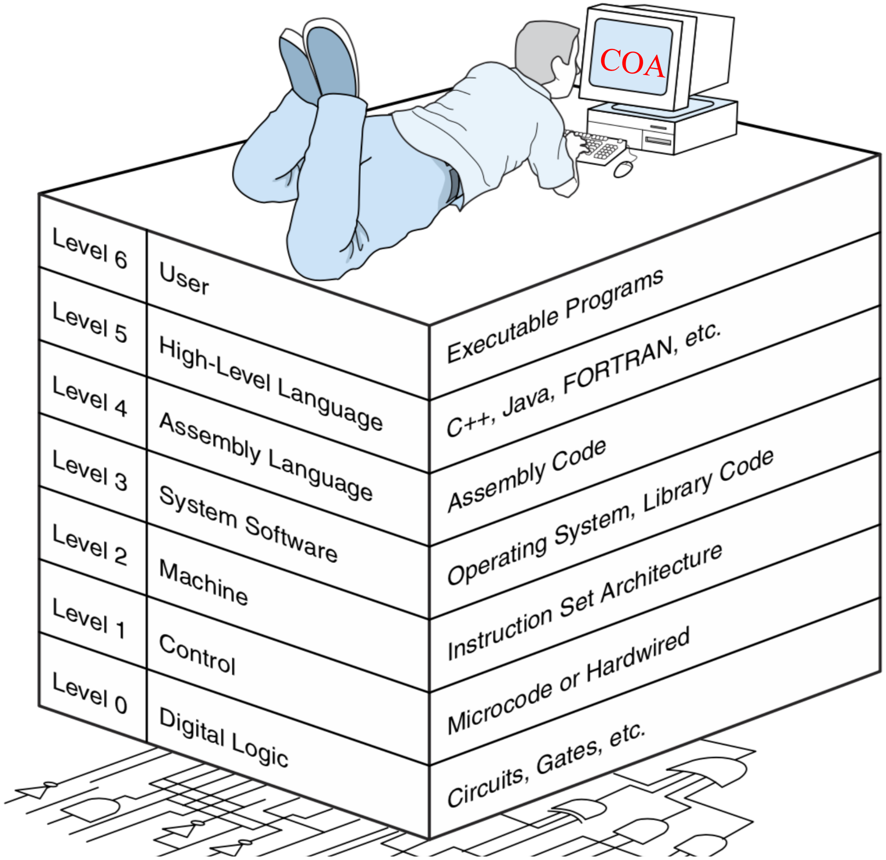


Figure: The Abstract Levels of Modern Computing Systems

Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.26.

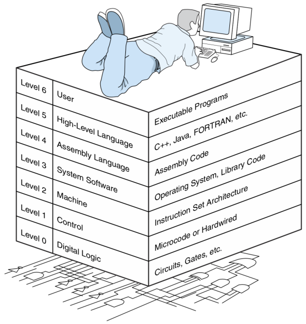


Table: Commonly accepted layers in virtual machines.

Level 6: The User Level	❑ Program execution and user interface level. ❑ The level with which we are most familiar.
Level 5: High-Level Language Level	❑ The level with which we interact when we write programs in languages such as C, Pascal, Lisp, and Java.
Level 4: Assembly Language Level	❑ Acts upon assembly language produced from Level 5, as well as instructions programmed directly at this level.

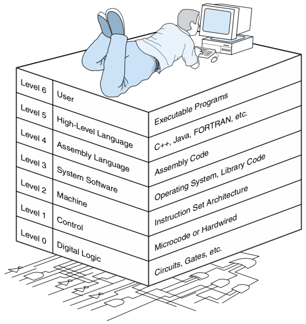


Table: ... Commonly accepted layers in virtual machines.

Level 3: System Software Level	❑ Controls executing processes on the system. ❑ Protects system resources. ❑ Assembly language instructions often pass through Level 3 without modification.
Level 2: Machine / ISA Level	❑ Consists of instructions that are particular to the architecture of the machine. ❑ Programs written in machine language need no *compilers*, *interpreters*, or *assemblers*.

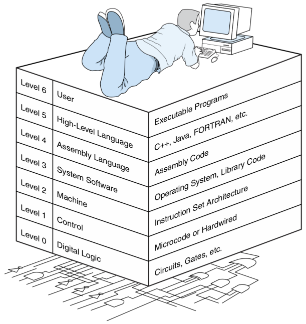
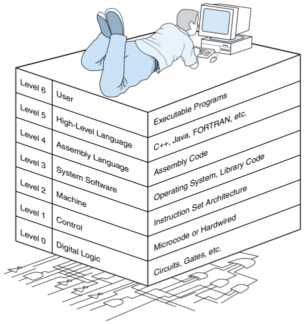


Table: ... Commonly accepted layers in virtual machines.

Level 1: Control Level	❑ A control unit decodes and executes instructions, and moves data through the system. ❑ Control units can be microprogrammed or hardwired. ➢ A microprogram is a program written in a low-level language that is implemented by the hardware. ➢ Hardwired control units consist of hardware that directly executes machine instructions.



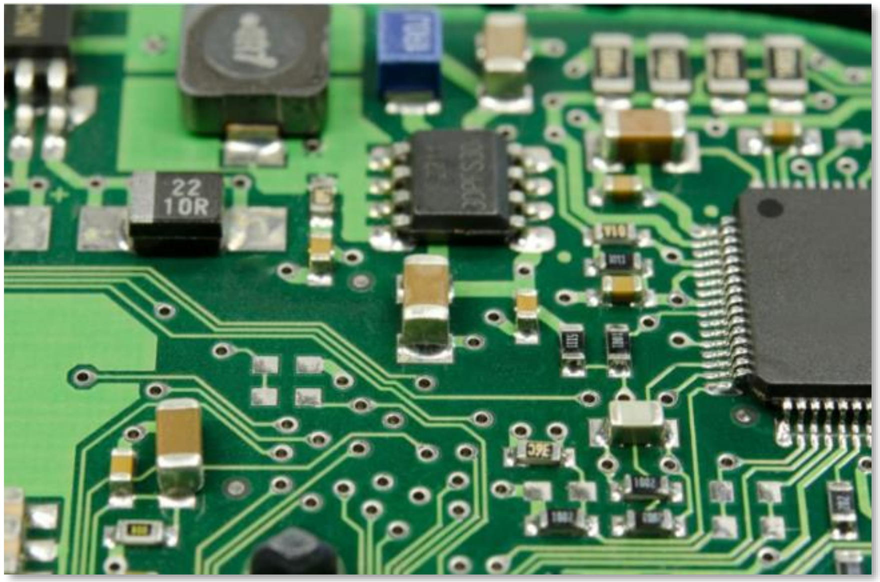


Table: ... Commonly accepted layers in virtual machines.

Level 0: Digital Logic Level	❑ This level is where we find digital circuits (the chips). ❑ Digital circuits consist of <u>gates</u> and <u>wires</u>. ❑ These components implement the mathematical logic of all other levels.

Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.27.
http://www.jps-pcb.com/upfile/2016/06/20160629190236_660.png

Module 1

Introduction

- Overview
- Basic Measurement Terminology

1.6 An Example System

Overview

- This section will introduce some of the vocabulary that is specific to computers.
- This jargon can be confusing, imprecise, and intimidating.
- For the sake of discussion, the next slide has provided a facsimile computer advertisement.

What does it all means ?

L1 cache? PCI? MHz? MB? USB?

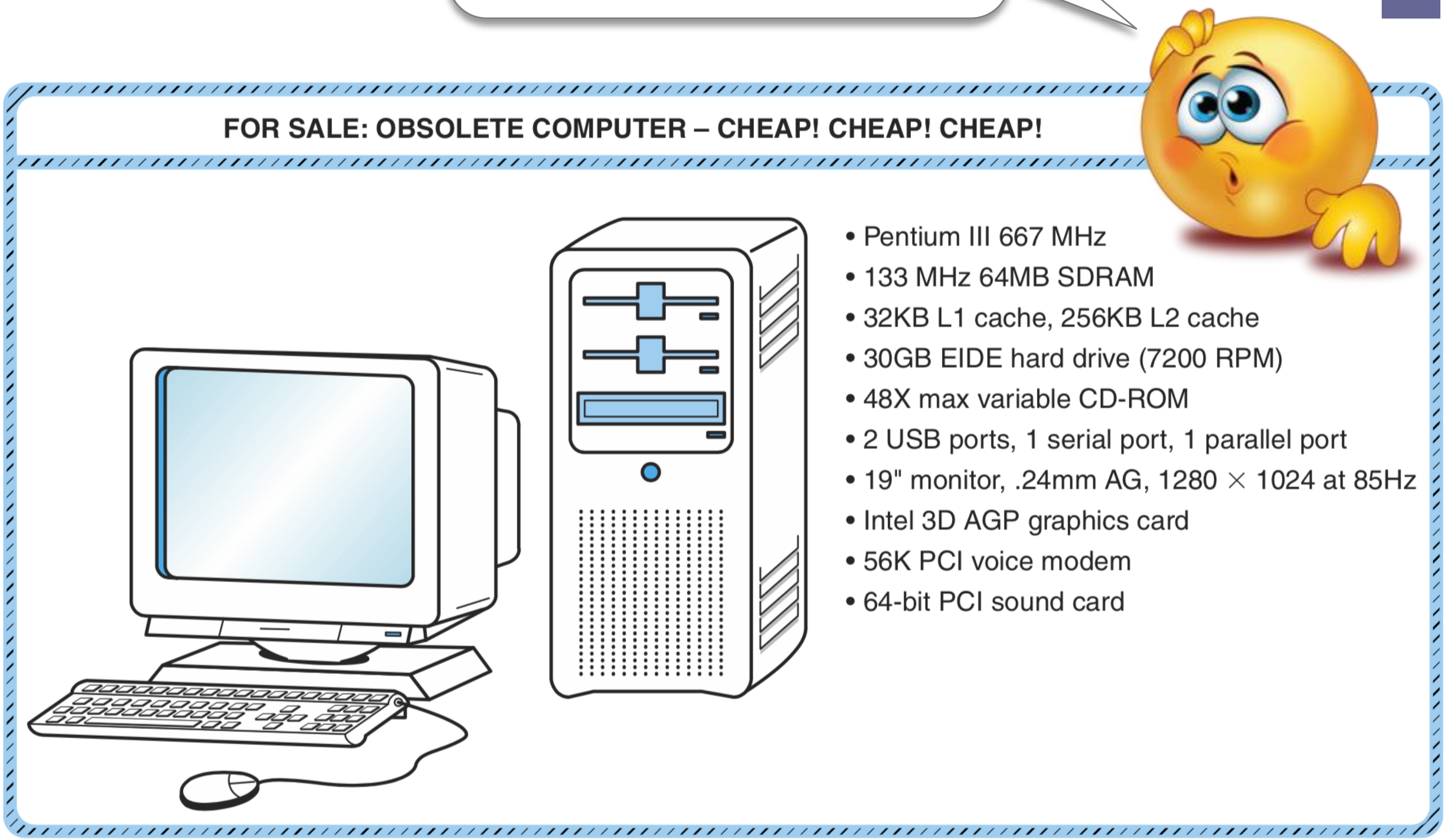


Figure: A typical computer advertisement.

Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.5.

Without having a handle on such terminology, you would be hard-pressed to know whether the stated system is a wise buy, or even whether the system is able to serve your needs.

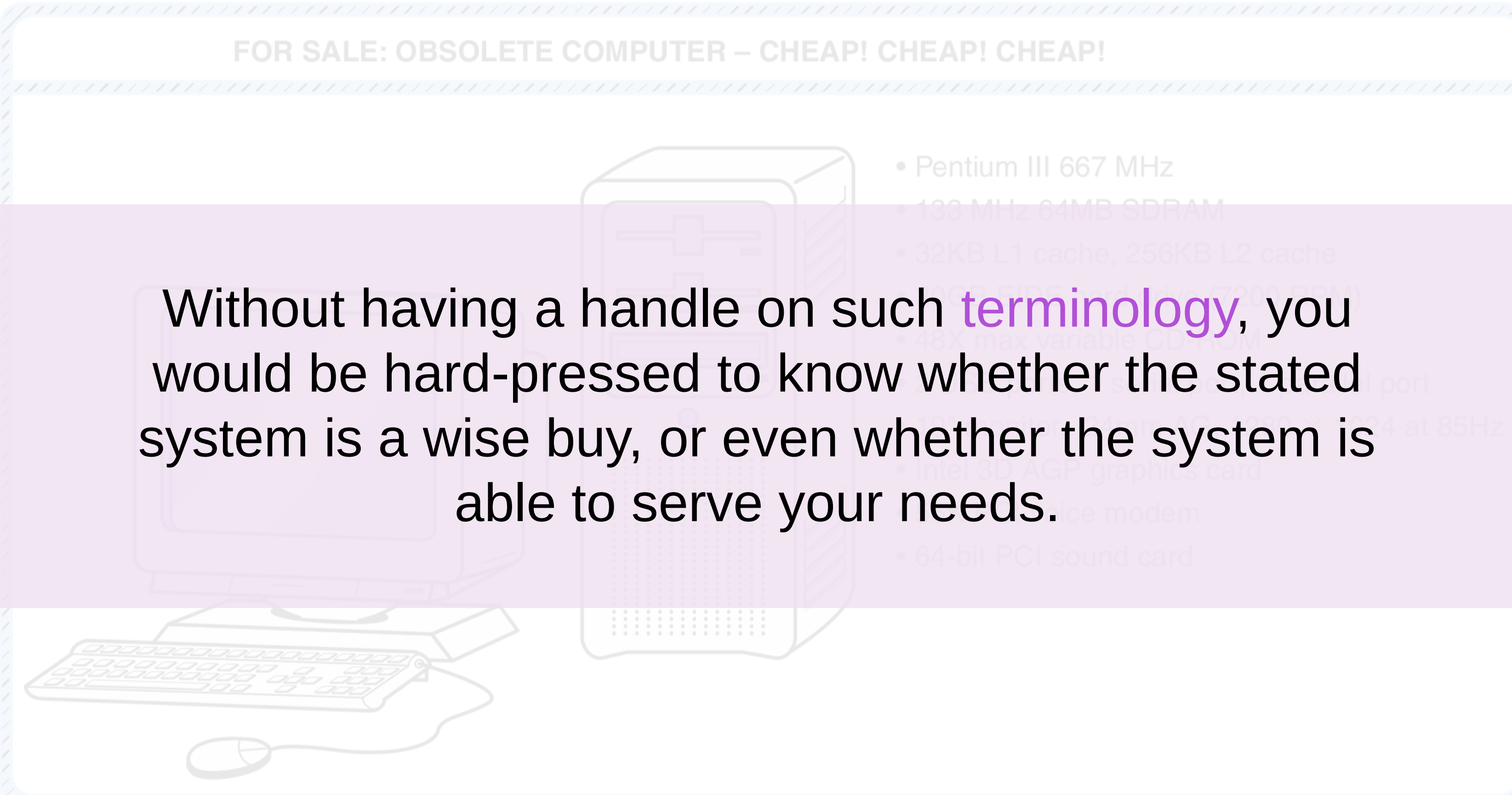


Figure: A typical computer advertisement.

Basic Measurement Terminology

Kilo- (K)	(1 thousand = $10^3 \approx 2^{10}$)	Milli- (m)	(1 thousandth = $10^{-3} \approx 2^{-10}$)
Mega- (M)	(1 million = $10^6 \approx 2^{20}$)	Micro- (μ)	(1 millionth = $10^{-6} \approx 2^{-20}$)
Giga- (G)	(1 billion = $10^9 \approx 2^{30}$)	Nano- (n)	(1 billionth = $10^{-9} \approx 2^{-30}$)
Tera- (T)	(1 trillion = $10^{12} \approx 2^{40}$)	Pico- (p)	(1 trillionth = $10^{-12} \approx 2^{-40}$)
Peta- (P)	(1 quadrillion = $10^{15} \approx 2^{50}$)	Femto- (f)	(1 quadrillionth = $10^{-15} \approx 2^{-50}$)

(a) Measures of capacity and speed (b) Measures of time and space

Figure: Common Prefixes Associated with Computer Organization and Architecture

- Whether a metric refers to a power of 10 or a power of 2, typically depends upon what is being measured.

Example: Capacity and speed.

- *Hertz* = clock cycles per second (frequency)
  - $1MHz$ = 1,000,000Hz
  - Processor speeds are measured in *MHz* or *GHz*.

- *Byte* = a unit of storage
  - $1KB = 2^{10} = 1024$ *Bytes*.
  - $1MB = 2^{20} = 1{,}048{,}576$ *Bytes*.
  - Main memory (RAM) is measured in *MB*.
  - Disk storage is measured in *GB* for small systems, *TB* for large systems.

Example: Time and space.

- *Millisecond* = 1 thousandth of a *second*
  - Hard disk drive access times are often 10 to 20 *milliseconds*.
- *Nanosecond* = 1 billionth of a *second*
  - Main memory access times are often 50 to 70 *nanoseconds*.

- *Micron* (micrometer) = 1 millionth of a *meter*
  - Circuits on computer chips are measured in *microns*.

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- We note that cycle time is the reciprocal of clock frequency.
- A bus operating at 133*MHz* has a cycle time of 7.52 *nanoseconds*:

133,000,000 *cycles/second* = 7.52 *ns/cycle*

Lets go back to the advertisement …

Video 2 – Computer Clock

- What is clock in a computer? Please watch this YouTube video
- https://www.youtube.com/watch?v=Z5JC9Ve1sfI

The microprocessor is the "brain" of the system. It executes program instructions.

This one is a Pentium III (Intel) running at 667*MHz*.

A system bus moves data within the computer. The faster the bus the better.

This one runs at 133*MHz*.

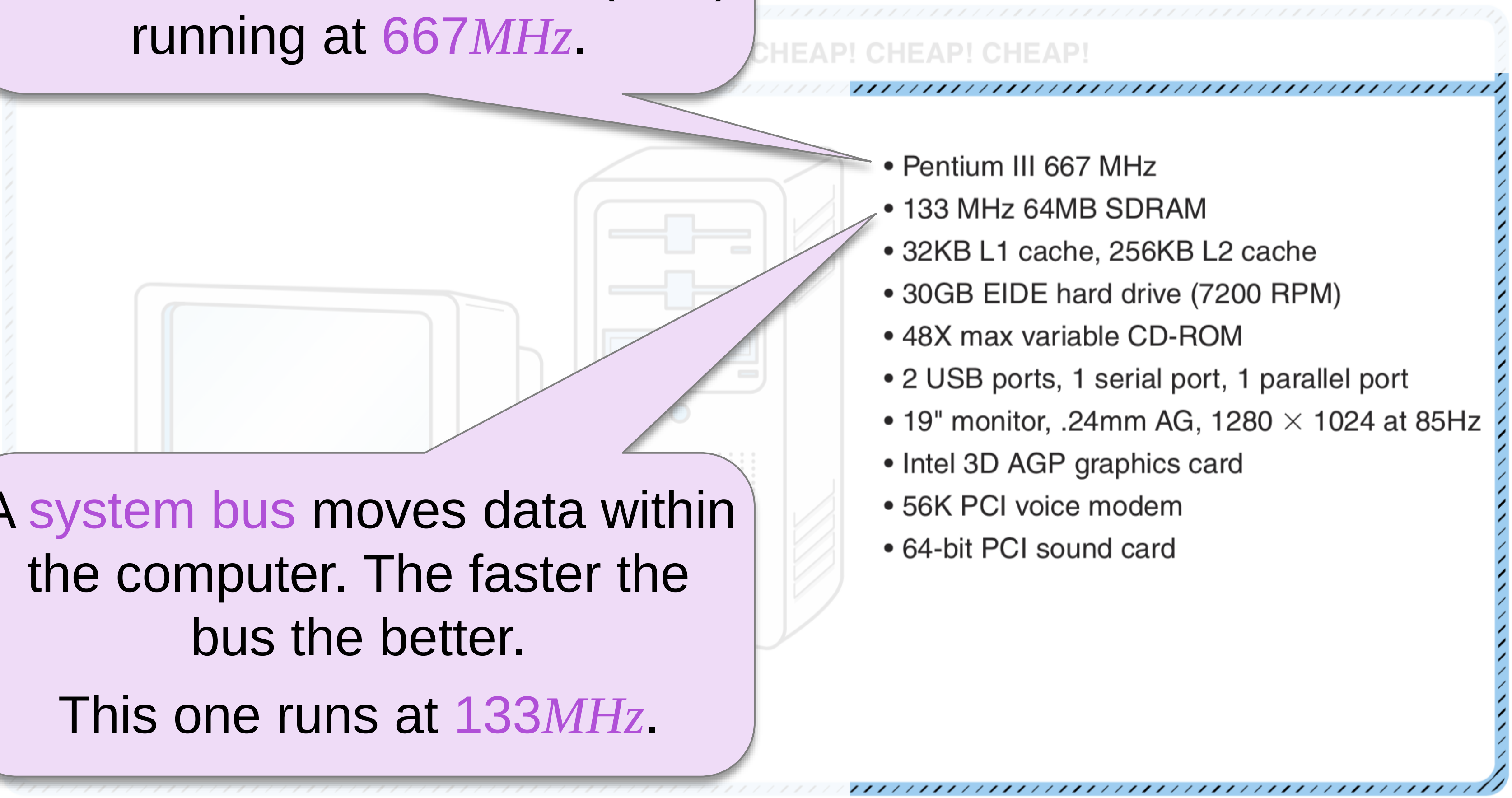

Figure: A typical computer advertisement.

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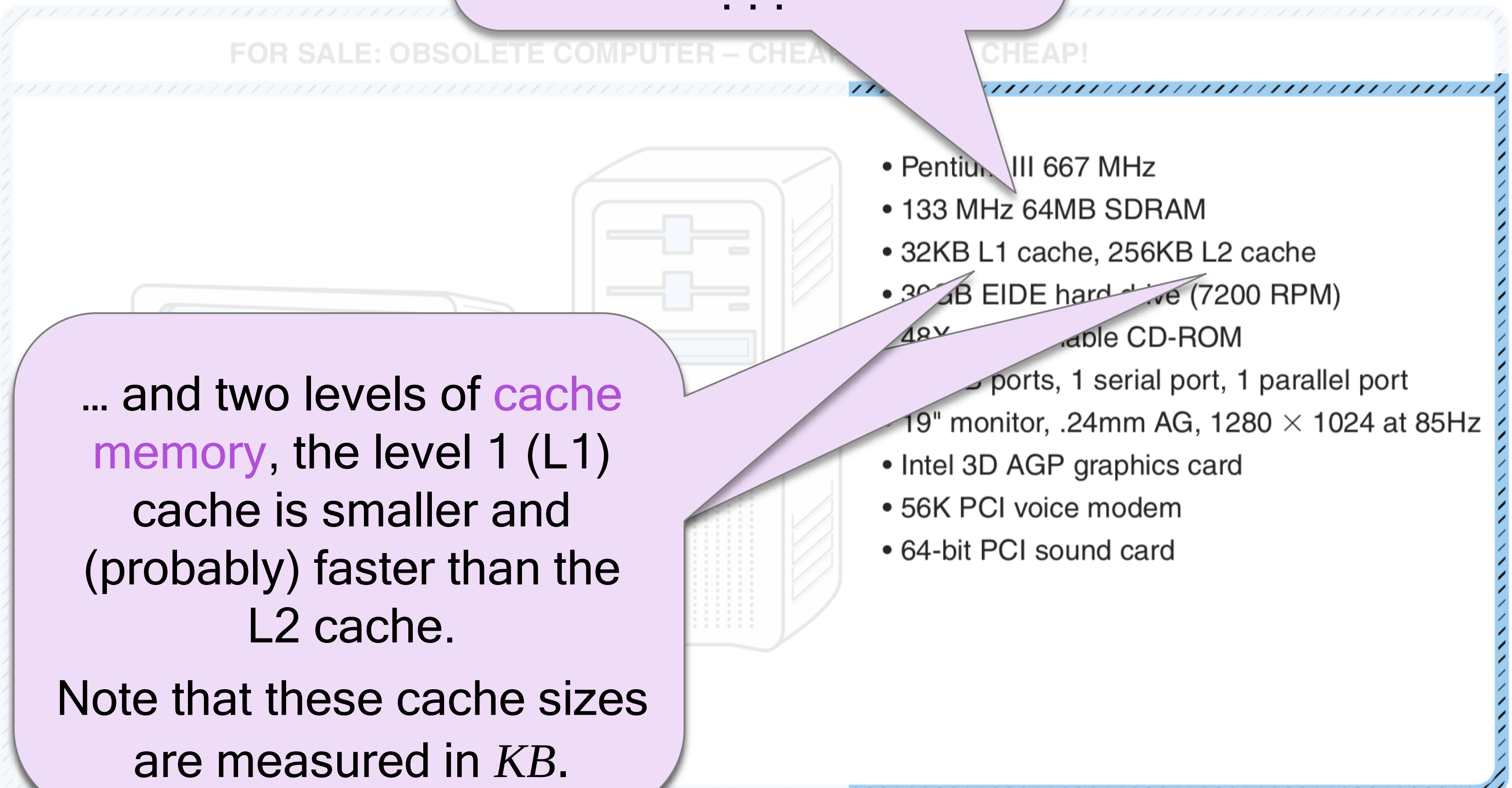
- Computers with large main memory capacity can run larger programs with greater speed than computers having small memories.

- RAM is an acronym for Random Access Memory.
  - Random access means that memory contents can be accessed directly if you know its location.
- Cache is a type of temporary memory that can be accessed faster than RAM.

This system has 64MB of (fast) Synchronous Dynamic RAM (SDRAM) . . .



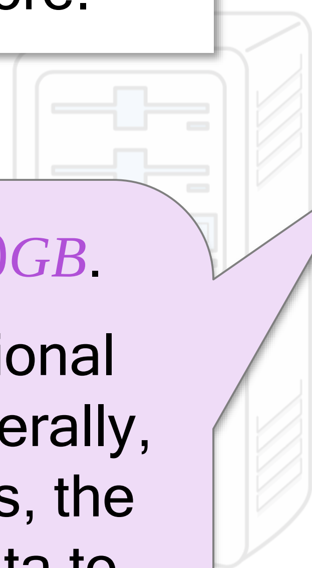
… and two levels of cache memory, the level 1 (L1) cache is smaller and (probably) faster than the L2 cache.

Note that these cache sizes are measured in *KB*.

Figure: A typical computer advertisement.

Hard disk capacity determines the amount of data and size of programs you can store.

CHEAP! CHEAP! CHEAP!



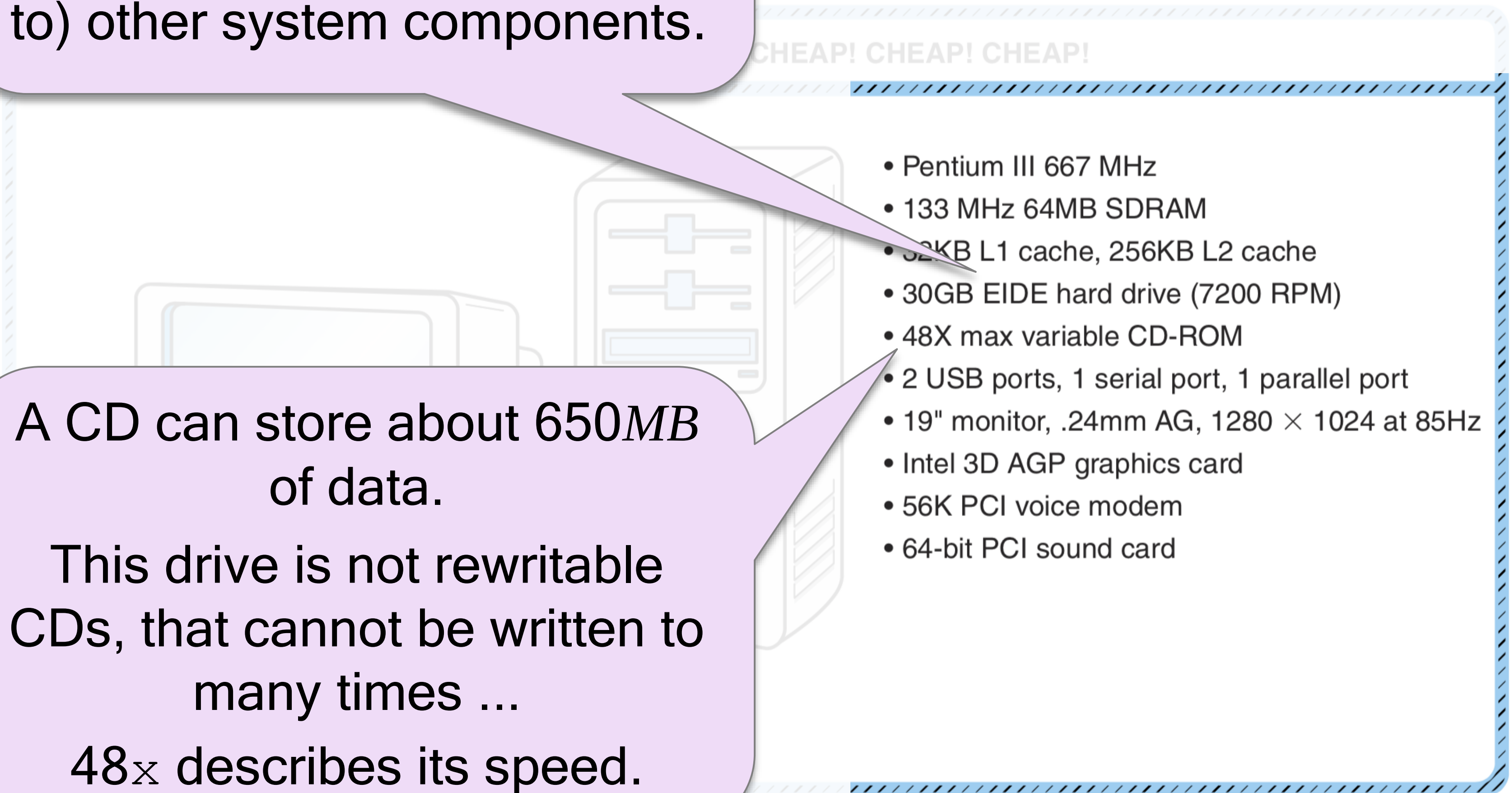
- Pentium III 667 MHz
- 133 MHz 64MB SDRAM
- 32KB L1 cache, 256KB L2 cache
- 30GB EIDE hard drive (7200 RPM)
- 48X max variable CD-ROM
- 2 USB ports, 1 serial port, 1 parallel port
- 19" monitor, .24mm AG, 1280 × 1024 at 85Hz
- Intel 3D AGP graphics card
- 56K PCI voice modem
- 64-bit PCI sound card

This one can store 30*GB*.

7200 *RPM* is the rotational speed of the disk. Generally, the faster a disk rotates, the faster it can deliver data to RAM. (There are many other factors involved).

Figure: A typical computer advertisement.

EIDE stands for *Enhanced Integrated Drive Electronics*, which describes how the hard disk interfaces with (or connects to) other system components.



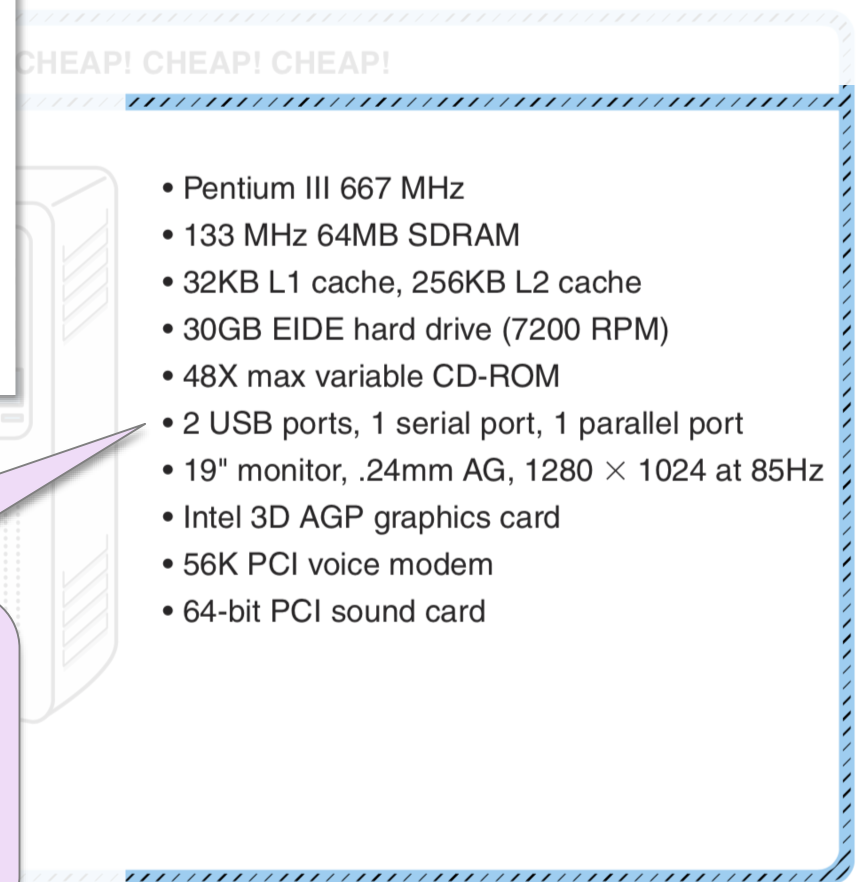
A CD can store about 650*MB* of data.

This drive is not rewritable CDs, that cannot be written to many times ...

48x describes its speed.

Figure: A typical computer advertisement.

- Ports allow movement of data between a system and its external devices.
- Most desktop computers come with two kinds of data ports: serial ports and parallel ports.



This system equipped with a special serial connection called a USB (*Universal Serial Bus*) ports.

Figure: A typical computer advertisement.

Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.9.

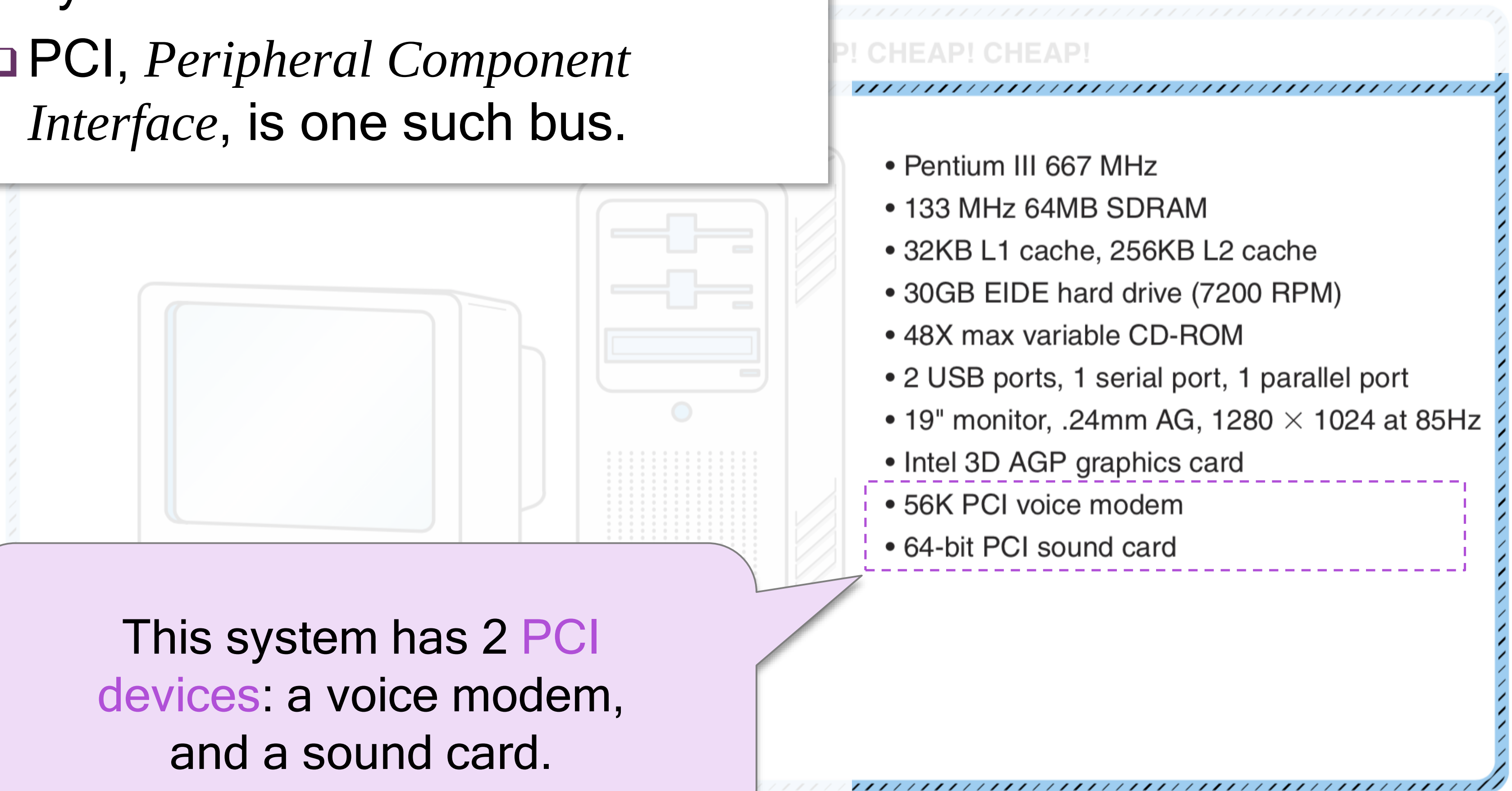
- Serial ports send data as a series of pulses along one or two data lines.
- Parallel ports send data as a single pulse along at least eight data lines.
- USB (*Universal Serial Bus*), is an intelligent serial interface that is self-configuring.
    - ➢ It supports "plug and play".

Serial Ports

Parallel Ports

Linda Null and Julia Lobur (2003). *The Essentials of Computer Organization and Architecture.* United States: Jones and Bartlett Publishers. p.9.
https://www.beyondrevelation.co.za/wp-content/uploads/2017/02/Adaptor-15-pin-female-to-male-VGA-INSTAL3.gif
https://cdn.techterms.com/img/lg/parallel_port_105-2.jpg

- System buses can be augmented by dedicated I/O buses.
- PCI, *Peripheral Component Interface*, is one such bus.



This system has 2 PCI devices: a voice modem, and a sound card.

Figure: A typical computer advertisement.

The number of times per second that the image on a monitor is repainted is its *refresh rate*.

The *dot pitch* of a monitor tells us how clear the image is (Resolution).

This one has a dot pitch of 0.24*mm* and a refresh rate of 85*Hz*.

This monitor is further supported by an AGP (*Accelerated Graphics Port*) graphics card.

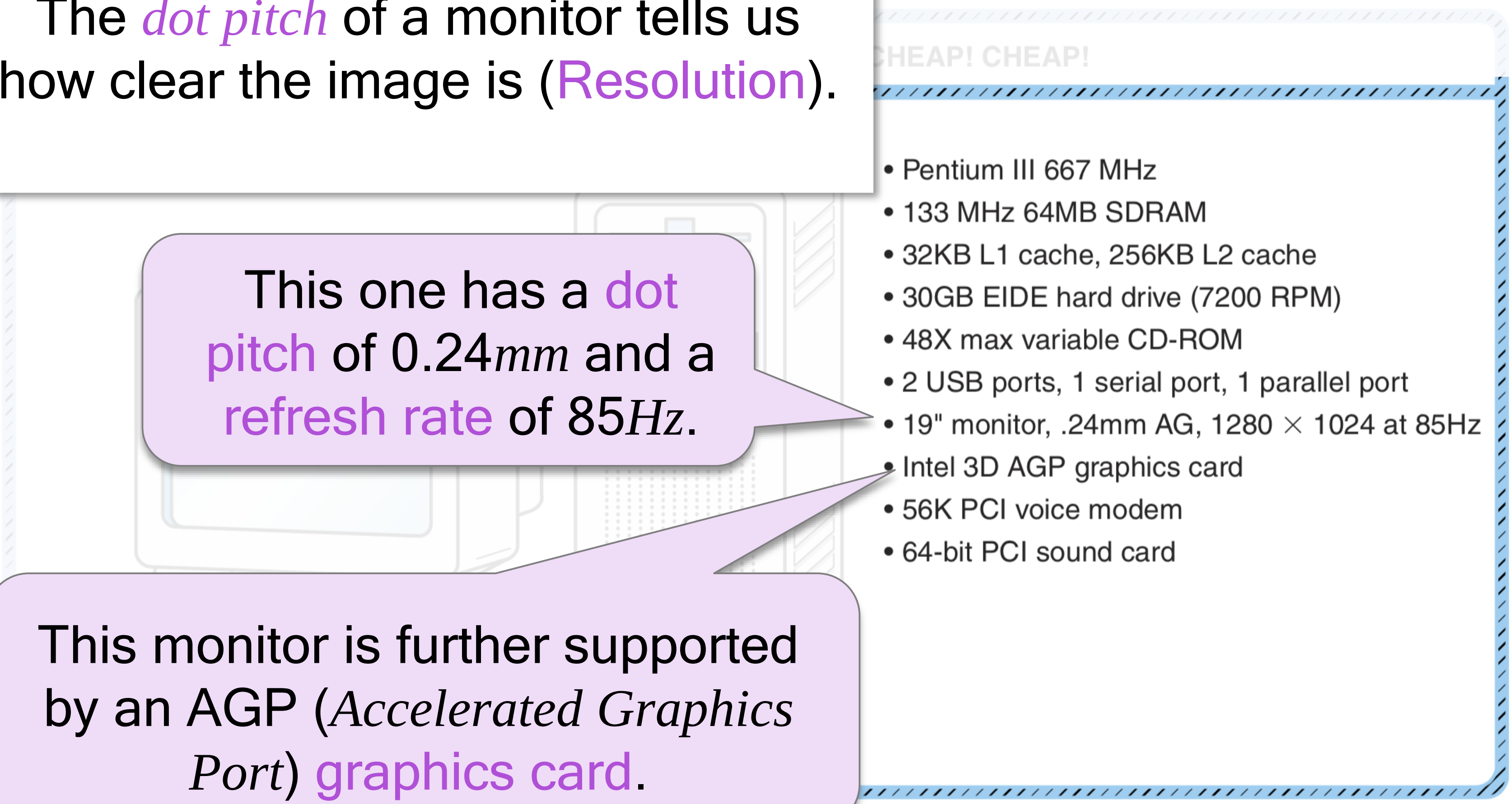


Figure: A typical computer advertisement.

1.7 Summary

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- The distinction between computer organization and computer architecture is not clear-cut.
- In fact, neither computer organization nor computer architecture can stand alone. They are interrelated and interdependent.
- Students can truly understand each of these fields only after they comprehend both throughout the remainder of this course.
- This leads to a deeper understanding of computers and computation – the heart and soul of computer science.

Review Questions

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1.1 What, in general terms, is the distinction between computer organization and computer architecture?

1.2 What, in general terms, is the distinction between computer structure and computer function?

1.3 What are the four main functions of a computer?

1.4 List and briefly define the main structural components of a computer.

1.5 List and briefly define the main structural components of a processor.

Review Questions

1.6 What is a stored program computer?

1.7 What are the four main components of any general-purpose computer?

1.8 List and explain the key characteristics of a computer family.

1.9 What is the key distinguishing feature of a microprocessor?